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INFERIOR VENACAVAL OBSTRUCTION IN HEPATIC CIRRHOSIS

by

INGEMAR BERGSTRAND, CARL AXEL EKMAN and ROLF KOHLER

Cirrhosis of the liver often produces narrowing or obstruction of the intrahepatic portal ramifications by pressure from scar tissue or regenerating nodules (MCINDOE 1928, KELTY et coll. 1950). These changes have been demonstrated by percutaneous splenic phlebography (BERGSTRAND 1957, BERGSTRAND & EKMAN 1957).

The inferior vena cava crosses the liver in a deep fossa (fissura venae cavae) or occasionally is surrounded completely by hepatic tissue. The caudate lobe is situated close to and left of the inferior vena cava. Thus, during its intrahepatic course, this vessel is fixed rigidly on all sides and is easily subjected to compression from expansive processes arising outside the liver (enlarged pancreas, lymph nodes) or within its substance (cysts, abscesses, gummas, primary or secondary neoplasms, or the regenerating nodules in cirrhosis of the liver). The effect of such slowly developing compression of the inferior vena cava is clinically less dramatic than a similar obstruction of the portal vein and has therefore received less attention in the medical literature. After a surgically created portacaval shunt the volume of blood emptying into the prehepatic portion of the inferior vena cava is increased by 1 to 1.5 l/min. Any narrowing

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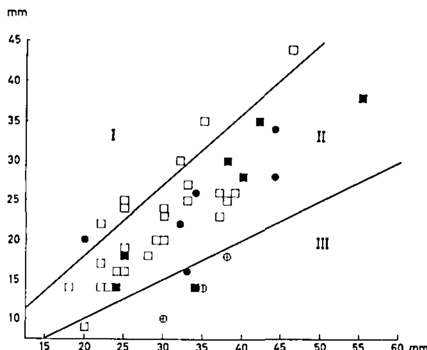


Fig 1 Distribution of 41 examinations according to the relation between prehepatic (X axis) and intrahepatic (Y axis) diameters

Group I $\frac{\text{Prehepatic diam}}{\text{intrahepatic diam}} = \frac{1}{1} - \frac{10}{9}$

Group II $\frac{\text{Prehepatic diam}}{\text{intrahepatic diam}} = \frac{10}{9} - \frac{2}{1}$

Group III $\frac{\text{Prehepatic diam}}{\text{intrahepatic diam}} = \text{More than } \frac{2}{1}$

■ Ascites before portacaval shunt
+) Ankle edema after shunt
● Ascites before and ankle edema after shunt

of the hepatic or suprahepatic portion of the inferior vena cava would then theoretically produce clinically significant hemodynamic changes

The present communication is concerned with this problem Splenoportography has been performed after the creation of a portacaval shunt in a group of cases of liver cirrhosis advanced enough to have portal hypertension The degree of narrowing of the intrahepatic portion of the inferior vena cava has been estimated on the basis of this examination The roentgenographic findings have then been correlated with the macroscopic appearance of the liver, the decrease in portal pressure after establishment of the shunt, the presence or absence of ascites before and after surgery, and the occurrence of edema of the ankle following operation

Previous reports PLEASANTS (1911) described 296 cases collected from the literature as well as 18 of his own cases of obstruction of the inferior vena cava In 31 of these cases the obstruction, often complicated by thrombosis was

caused by non malignant liver disease (abscess 8 cirrhosis 10 syphilis 7 echinococcus cysts 6) In 9 cases the obstruction was due to hepatic carcinoma

FERRIS & BLANKENHORN (1941) described 5 consecutive cases of solitary abscess in the right lobe of the liver that caused obstruction by pressure external to the inferior vena cava An elevated femoral vein pressure (as compared to the cubital vein pressure) was demonstrated in all these cases On the other hand cases with a symmetrically enlarged liver due to cirrhosis leukemia hepatitis or carcinomatosis had no such elevation of the femoral vein pressure It was suggested that pressure measurements could be used in the differential diagnosis between liver abscess and other intrahepatic lesions

DOS SANTOS (1935) first described the clinical application of roentgeno graphy of the inferior vena cava by direct contrast injection The most common indication for this examination is the investigation of peri aortic lymph nodes metastases in carcinoma of the testis or malignant lymphoma (HELANDER & LINDBOM 1956 1959, FUCHS 1961, and others) Only occasional reports are found of expansive intrahepatic lesions having been disclosed by this method VIALLET et coll (1957) published cavograms of four cases of hepatosplenomega ly showing varying degrees of intrahepatic inferior vena caval compression BOURGEON & GUNTZ (1959) described cases with hypertrophy of the caudate lobe and with liver tumors in which cavography had shown caval narrowing Intrahepatic collateral connections may in such cases develop between hepatic veins caudal to the compressing intrahepatic lesion and those emptying cranial to it

HELANDER & LINDBOM (1959) observed deformation of the vena cava in its passage through the liver in only a few cases One of these was caused by hepatic metastases the lumen of the vessel was strikingly irregular and somewhat narrowed In another case with a diffusely enlarged liver there was stenosis of the inferior vena cava with regular contours of its cranial portion

PETERSEN et coll (1961) compared the findings on cavography in five normal subjects with five cases of cirrhosis Despite large individual variations they found a decrease in the intrahepatic vessel area in relation to the suprahepatic vessel area in cases of cirrhosis as compared to normal cases These findings explained the pressure gradient in cirrhosis between the intrahepatic and suprahepatic parts of the inferior vena cava presented in a previous paper (WINKLER et coll 1959) The possibility that the findings might be functional and caused by the often coexistent ascites rather than by organic narrowing was discussed but was thought less likely

BERGSTRAND (1961) described a case of cirrhosis in which splenic phlebo graphy after portacaval shunt demonstrated a narrowing of the intrahepatic part of the inferior vena cava associated with clinical signs of incapacity of this vessel FILLER et coll (1962) state 'that a prominent caudate lobe of the liver may compress the left border of the vena cava at the level of the tenth to twelfth thoracic vertebra



Fig 2 Liver cirrhosis Splenoportograms a) Considerable shrinkage and condensation of intrahepatic portal ramifications portal hypertension with collateral circulation b) After portacaval shunt normal diameter of intrahepatic part of inferior vena cava

Material and methods The material consists of all cases with verified cirrhosis of the liver in which cavography or splenic phlebography after portacaval shunt was performed during the period 1954 to 1960 After exclusion of examinations with a non diagnostic concentration in the inferior vena cava there remained 41 examinations in 38 cases in which the prehepatic as well as the intrahepatic diameter of the vessel could be estimated (Figs 2—4)

The examinations were performed with a vertical beam and with the patient supine The maximum diameter of the ordinarily evenly contoured prehepatic part of the inferior vena cava was measured and compared with the minimum diameter of the intrahepatic portion of the vessel FFD 90 cm No account was taken of the differences in geometric enlargement due to differences in body size and shape The results of the measurements from all the 41 examinations are given in the diagram of Fig 1 The prehepatic diameter of the inferior vena cava is plotted along the X axis and the smallest intrahepatic diameter along the Y axis The examinations have been divided into three groups (I) *no, or very slight, difference between the prehepatic and intrahepatic* diameters (1 1 to 10 9), (II) moderate difference (10 9 to 2 1), and (III) considerable difference (greater than 2 1)

The cases in these three groups have been compared under the following categories (1) Size, consistency and type of nodularity of the cirrhotic liver as judged at laparotomy or autopsy (38 cases), (2) decrease in portal pressure after establishment of the portacaval shunt (37 cases), (3) presence or absence of ascites before and after shunt (41 examinations) and (4) occurrence of edema of the ankle after shunt (41 examinations)

Results

There was no, or very slight, decrease in the intrahepatic caval diameter as compared to the prehepatic in seven examinations (group I), a moderate



Fig 3 Liver cirrhosis Splenoportograms a) Distortion of intrahepatic portal ramifications portal hypertension with collateral circulation b) Considerable narrowing of intrahepatic portion of inferior vena cava

decrease in 28 examinations (group II) and a considerable reduction of the diameter of the hepatic caval segment in six examinations (group III) (Fig 1)

The size, consistency and type of cirrhotic nodularity of the liver did not differ in the three groups

The decrease in portal vein pressure after portacaval shunt in group I was 24 to 9 cm H_2O (mean 16 cm H_2O) in group II 25 to 9 cm H_2O (mean 17 cm H_2O), and in group III 20 to 7 cm H_2O (mean 11 cm H_2O)

Ascites before portacaval shunt was present in one of the seven group I cases, in ten of the twenty eight group II cases and in two of the six group III cases The ascites disappeared in all cases after the shunt was established

Ankle edema occurred after portacaval shunt in one case in group I (the same case in which there had been ascites) in four group II cases (all of which had had ascites) and in four group III cases (one of these four had had ascites preoperatively)

Discussion

Fuchs (1961) using material from the roentgendiagnostic department of the University of Lund has shown that in normal cavograms the intrahepatic segment of the inferior vena cava has the same diameter as the prehepatic portion According to Helander & Lindbom (1959) in normal cases the vena cava presented a uniform diameter in the anteroposterior views The caudate lobe of the liver was often discernible in anteroposterior views as a regular arciform impression in the left wall of the inferior vena cava The sagittal diameter of the inferior vena cava at the level of the liver is larger than the frontal (Helander & Lindbom 1959 Fuchs 1961)

It has been claimed that layering of contrast medium and incomplete mixing with the blood is important especially in veins with slow circulation and that the vascular anatomy may be misjudged if examinations are performed with



Fig 4 Splenoportograms a) One month after portacaval shunt b) 6 months after shunt slight increase in the caval diameter in the prehepatic region

a vertical beam (KJELLBERG 1943, GREITZ 1954) The writers feel that these arguments may be disregarded in the present material for the following reasons prior to entering the vena cava through the shunt some mixing of contrast medium and blood occurs in the portal vein Complete mixing of this opacified blood from the portal vein with the caval blood is favoured by the large portacaval pressure gradient which enhances portal drainage and produces turbulence, and by the fact that the portal vein enters the ventral aspect of the inferior vena cava at right angles to this vessel The contrast column was always well delineated and did not change in appearance between different serial films Cases with insufficient contrast density in the inferior vena cava were excluded in order to make the results as reliable as possible The diameters measured are consequently considered to indicate the true frontal dimension of the vessel

The grouping of the cases according to the roentgenographically demonstrable differences in diameter was done by two of the authors (B and K) independently of the tabulation of the clinical data which was performed by the third author (E), this ensured that the correlation between intrahepatic caval obstruction and the different clinical data was completely objective

The material examined is composed of cases of portal hypertension in which cirrhotic changes considerably encroached upon the intrahepatic portal system (Figs 2a and 3a) Despite this there was marked narrowing of the intrahepatic portion of the inferior vena cava in only six of the 41 cases (Fig 3b) The results indicate that a considerable narrowing of the inferior vena cava is not usual in cirrhosis of the liver regardless of the fact that, due to the technique used, only cases with frontal narrowing were recorded

The absence of any correlation between the degree of caval obstruction and the macroscopic appearance of the liver is difficult to explain The few autop

sies performed were not particularly concerned with the present problem. The relatively small decrease in portal pressure after portacaval shunt in those cases with considerable caval obstruction as compared with those with less or no obstruction indicates that such narrowing of the inferior vena cava has some hemodynamic importance in relation to the function of the portacaval shunt.

Ascites in cirrhosis of the liver is caused by the combined effects of portal hypertension and of the hypoproteinemia due to the reduction in liver function. Ascites generally disappears after a portacaval shunt which decompresses the portal system (Ekman, 1957). A considerable narrowing of the intrahepatic segment of the inferior vena cava would possibly diminish the effect of a portacaval shunt and obviate or diminish its favourable effect on the ascites. However, in this material the disappearance of ascites after decompression of the portal system by portacaval shunt even in those cases with considerable caval narrowing indicates that any such influence on the formation of ascites is negligible.

The occurrence of ankle edema after portacaval shunt may be attributed to hypoproteinemia. Other possible causes such as cardiac decompensation or iliac vein thrombosis were not found during the thorough clinical examinations before and after surgery. However, the occurrence of edema of the ankle in four of six cases with considerable narrowing of the intrahepatic segment of the inferior vena cava as compared with five of 35 cases without such a lesion indicates the clinical importance of caval obstruction. If cases with ascites before portacaval shunt and consequently with severely damaged liver function are excluded, the positive correlation is even more evident (three of four cases with obstruction as compared with none of 24 cases with less significant inferior vena caval obstruction).

SUMMARY

An investigation of the degree of inferior vena caval obstruction due to regenerating liver nodules in 41 examinations in 38 cases of hepatic cirrhosis associated with portal hypertension is reported. Marked obstruction was present in only six of the cases. The obstruction of the inferior vena cava did not influence the disappearance of ascites after portacaval shunt but favoured the occurrence of edema of the ankle.

ZUSAMMENFASSUNG

Es wird über eine Untersuchung des Schweregrades des Verschlusses der Vena cava inferior, bedingt durch regenerierendes Lebergewebe, anhand von 41 Untersuchungen in 38 Fällen von Lebercirrhose kombiniert mit portalem Überdruck berichtet. Der Grad des Verschlusses der Vena cava inferior beeinflusste nicht das Verschwinden des Ascites, aber begünstigt nach portacavaler Anastomose das Auftreten von Ödem am Fussgelenk.



Fig 4 Splenoportograms a) One month after portacaval shunt b) 6 months after shunt slight increase in the caval diameter in the prehepatic region

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RÉSUMÉ

Les auteurs présentent une étude sur le degré d'obstruction de la veine cave inférieure par des nodules de régénération hépatique dans 41 examens de 38 cas de cirrhose hépatique accompagnée d'hypertension portale. Il n'y avait une obstruction marquée que dans six de ces cas. L'obstruction de la veine cave inférieure n'a pas d'influence sur la disparition de l'ascite, mais après shunt entre les systèmes cave et porte elle favorise l'apparition de l'oedème des chevilles.

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FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR DOCENT ROLF KOHLER), UNIVERSITY SURGICAL CLINICS HELSINKI FINLAND

EVACUATION OF THE NORMAL LARGE INTESTINE

by

ROLF KOHLER

Although the motor activity of the large bowel may usually be determined by means of a barium meal an assessment of pathologic conditions demands a detailed knowledge of normal colonic filling and evacuation Little on this subject is found in the literature a fact that prompted the present investigation of the normal variability of colonic function by means of a small contrast meal It was considered that this special meal would produce the minimal interference with the normal physiology of the colon

Earlier investigations Motor activity of the colon has attracted a good deal of interest Information on this complex procedure is provided e g in the textbook of SCHINZ & coll (1952) Evacuation of the intestinal contents which is of special interest in the present work is mostly effected by the mass movements of the colon observed as early as 1909 by HOLZKNECHT These movements occur at intervals of several hours and transpose the intestinal contents by stages over long stretches

KANTOR (1932) observed the emptying of the colon roentgenologically in 844 unspecified cases The standard barium meal was employed, the quantity is not indicated but may be assumed to have been considerable A hard rectal impaction was encountered in over 18 per cent of cases and had to be removed by artificial means The method was therefore highly unphysiologic and for

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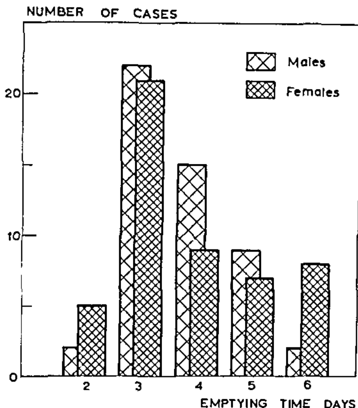


Fig 1 Emptying time in days for 50 normal colons of each sex

that reason the results may probably be considered unreliable Films were taken every 24 hours after the ingestion of the meal, until the colon was entirely empty, and the number of spontaneous stools was recorded The normal rate of emptying of the colon was found by KANTOR to be 72 hours

KOHLER's well known textbook discusses the normal emptying time of the large intestine and referred as late as 1939 to the 1911—1912 work of the pioneer RIEDER The latter gave two healthy test subjects a contrast meal containing bismuth carbonate A survey roentgenogram covering a field extending from the bases of the lungs to the upper part of the thighs, was taken roughly every half hour for about 24 hours The author regretted that the total number of exposures had to be cut down in each case to 45 and 47, respectively, to avoid erythema of the skin The investigation showed that the contrast medium reached the sigmoid colon in 12 hours and that its main bulk lay in the sigmoid colon and rectum at 24 hours

FANTUS, KOPSTEIN and SCHMIDT (1940) investigated the influence of bran on *intestinal motility by giving this substance mixed with 60 to 70 g barium* sulphate to 126 normal subjects aged between 20 and 30 years, 12 of whom



Fig 2 (The large intestine emptied in 48 hours) At 24 hours main part of the contrast medium lies in the sigmoid colon and rectum





Fig 3 (The large intestine emptied in 72 hours) *Left* at 24 hours the medium is fairly evenly distributed throughout the large bowel *Right* at 48 hours except for small traces in the cecum all the medium lies in the rectosigmoid region

were women The result of the study which was repeated in the same series was not very clearly reported but was roughly as follows of the 126 subjects the colon emptied in 24 hours in one in 48 hours in 38 in 72 hours in 62 in 96 hours in 20 and in 120 hours in 5 of them The authors observed marked physiologic variations in the emptying times in about 15 per cent of the test subjects

According to FELDMAN (1948), orally ingested barium is normally distributed throughout the colon in 24 hours The entire intestinal tract is usually empty in 48 to 72 hours

Material and Methods The present series comprised 50 males and 50 females aged between 21 to 30 years, who had never had intestinal symptoms and regularly had 1 to 2 formed stools a day The investigation was so arranged as not to interfere with normal colon function The test subjects were therefore instructed to lead a completely ordinary life and eat the normal amounts of food at the usual hours The barium meal consisted of 15 ml of barium sulphate emulsion and was ingested in the morning after the subject had had breakfast and the bowels had acted The quantity equalled 15 to 20 g of dry barium sulphate and rendered the colon sufficiently opaque every effort was made to keep the quantity low enough as not to disturb the intestinal transit The first film was taken the next morning that is to say 24 hours after the ingestion of the barium The remaining films were obtained at 24 hour inter



Fig 4 (The large intestine emptied in 96 hours) a) At 24 hours even distribution of medium throughout the large intestine b) At 48 hours the medium lies mostly in left half of the large intestine c) At 72 hours the medium lies now only in the rectosigmoid colon

vals until the colon was completely clear The number and consistency of stools passed during the 24 hours were to be reported at each examination Exposure factors *100 kV, 6—10 mAs, FFD 1 m*

Results

The cases are classified in Fig 1 according to the emptying time of the colon

The contrast medium was completely evacuated in 2 to 6 days in the subjects who had daily motions and were without intestinal symptoms The usual emptying time was 3 days The colon was empty in 2 days in only 7 per cent of subjects and in more than 3 days in about half the number of subjects The examination of male subjects gradually decreased towards the maximal period of 6 days whereas slow functioning large intestines were more numerous among women in whom the 4 and 6 day groups were almost equal in size

Careful examination of the films revealed the difference in the emptying mechanism of large intestines with different emptying rates Where emptying occurred in 2 days, the contrast medium has largely passed through the large bowel in 24 hours or was collected in the distal parts (Fig 2) If the emptying time was 3 days the medium was usually evenly distributed by 24 hours along the entire length of the large intestine At 48 hours it usually lay between the splenic flexure and the rectosigmoid junction with small residues in the ascending and transverse colon (Fig 3)

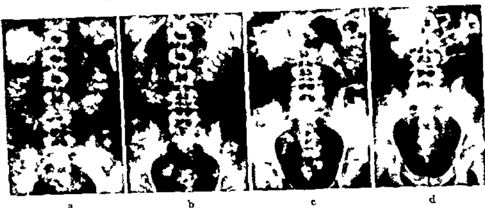


Fig 5 (The large intestine empt d n 120 hours) a) At 24 hours contrast medium in all parts of the large bowel tendency to faecal accumulation in l ft part of the transverse and descending colon b) At 48 hours less medium in proximal parts of bowel c) At 72 hours the proximal half of the large intestine is now almost empty d) At 96 hours insignificant traces of medium in the rectum

With a 4 day emptying time the contrast medium was usually evenly distributed at 24 hours throughout the large intestine or was present only as far as the splenic flexure, the remainder having been evacuated At 48 hours the transverse colon still contained a considerable amount of the medium while the distal parts of the bowel showed a varying degree of filling At 3 days the barium usually lay at the rectosigmoid junction (Fig 4)

When emptying occurred in 5 days the medium was seen in the first and last films in approximately the same regions as in the one day shorter emptyings The intermediate films showed that the retardation of intestinal transit occurred during the second to fourth day A certain tendency to accumulation of faeces was noted in the left part of the transverse colon and the descending colon (Fig 5) With emptying occurring in six days the medium at 24 hours filled the large intestine as far as the rectosigmoid region and evidence of accumulation was apparent in the left parts of the colon The colonic contents made slow progress during the following days and collected in the rectosigmoid region (Fig 6)

Discussion

A roentgen study of the progress of material through the large intestine is of considerable value for the assessment of pathologic intestinal function and is necessarily based upon an appreciation of the normal A great deal of work has been devoted to the study and classification of various types of constipation by means of barium meals or enemas although there appears to be only one methodical study of the emptying times of the large intestine in normal

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VIIth SYMPOSIUM NEURORADIOLOGICUM

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The blood supply of tumours of the colon and rectum	Mr J D Griffiths London
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The distribution within tumours of dyes and fluorescent substances by the blood system	Dr K A Newton London
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The Silvanus Thompson Memorial Lecture on X ray analysis of protein will be held by	Dr M F Perutz

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FROM THE ROENTGENDIAGNOSTIC AND CARDIOVASCULAR DEPARTMENTS OF THE PEDIATRIC CLINIC, KAROLINSKA SJUKHUSET STOCKHOLM, SWEDEN

ASSESSMENT OF THE PHYSIOLOGIC STATE IN ISOLATED VENTRICULAR SEPTAL DEFECT

by

JOSEPH E. WHITLEY, HARRY HERZENBERG and ULF RUDHE

It has previously been suggested that some aspects of the cardio vascular physiologic state in isolated ventricular septal defects may be evaluated by a conventional examination of the heart and lungs (KJELLBERG et coll 1955 & 1959 KEATS et coll 1957, SINGLETON et coll 1959, DUSHANE & KIRKLIN 1960 VICKERS et coll 1960 and YOUNG et coll 1960) Various aspects of the roentgenologic analysis of the routine chest examination have been considered to be of particular importance and include gross heart size, left atrial size, left ventricular size and the appearances of the pulmonary vascular tree

Eighty cases of isolated ventricular septal defect previously examined by routine chest roentgenography selective angiocardiography and electrocardiography (ECG) were studied in an effort to investigate this hypothesis the resultant information being compared and contrasted with the cardiac catheterization data obtained at the time of angiocardiography Four cases with concurrent functionally insignificant or repaired coarctations of the thoracic aorta were included in this group

The ability of those ordinarily reporting on conventional films was also tested regarding their ability to assess some of the information presented by angiocardiography and cardiac catheterization

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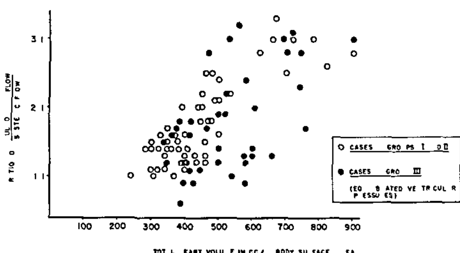


Fig 1 The relationship of gross heart size to the degree of left to right shunt present in cases of isolated ventricular septal defect

Material The 80 cases all had signs at cardiac catheterization and/or angio cardiographic evidence of an isolated ventricular septal defect There were 20 cases of 1 year of age or less and 60 cases above this age, the overall mean age being 4 6 years with a range of 2 months to 16 years The other cases available were eliminated because of incomplete left heart filling due to the technique employed, or for a reason that will be explained There were 42 males and 38 females in the series

Methods and Results

The cases were classified into groups by a method slightly modified from the one previously described by KJELLBERG et coll (1955, 1959) Briefly the groupings were made by the following criteria

Group I a Ventricular septal defect with no elevation of the right ventricular pressure at rest (peak systolic pressure < 30 mm Hg) and with no shunt dem onstrated by oximetry *(diagnostic level considered 1 volume %)*

Group I b Ventricular septal defect with no elevation of right ventricular pressure at rest and with a left to right shunt demonstrated with oximetry

Group II Ventricular septal defect with elevation of the right ventricular pressure but without equilibration of the left and right ventricular pressures (if left ventricular pressure unknown, less than 65 mm Hg in infancy and less than 80 mm Hg in childhood) with a left to right shunt demonstrated

Group III a Ventricular septal defect with equilibrated ventricular pressures (if left unknown, above the limits stated under group II) with a demonstrated left to right shunt and no peripheral desaturation at rest (oxygen saturation > 93 volume %)

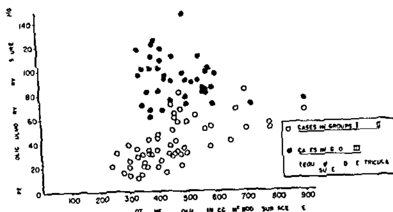


Fig 2 The relationship of gross heart s e to the degree of pulmonary hypertension present in cases of isolated ventricular septal d fect

Group III b Ventricular septal defect with equilibrated ventricular pressures (or as above) with demonstrated left to-right and right to-left shunt at rest (peripheral oxygen saturation < 93 volume %)

Group III c Ventricular septal defect with equilibrated ventricular pressures (or as above) with a demonstrated right to left shunt and no demonstrable left to right shunt at rest

The technique of cardiac catheterization and selective angiocardiography was described by KJELLBERG et coll (1959) The contrast injections in the group under consideration were uniformly made into the *right ventricle or the* right ventricular out flow tract

The total heart volumes were calculated from teleroentgenograms obtained in the recumbent position in infants and *the erect position* in children using the method described by JONSELL (1939) and LILJESTRAND et coll (1939) The heart volumes plotted *against the left to-right* shunt size estimated by oximetry and against the peak systolic pulmonary artery pressure are presented in Figs 1 and 2

The volumes of the left atria and left ventricles were estimated according to a method described by ARVIDSSON (1959, 1961) and employed by ARVIDSSON et coll (1960) and BUNNELL et coll (1961) Briefly the method consists in the measurement of the three diameters of a chamber from simultaneous bi plane angiocardiograms their correction for magnification and their substitu tion into an ellipsoid formula *Atrial* diameters were measured with an ac curacy of 1 mm and the volumes were abbreviated to the nearest milliliter ventricular diameters were measured with an accuracy of 2 mm and the volumes were rounded off to the nearest 5 ml *Due to the spatial* orientation of the true

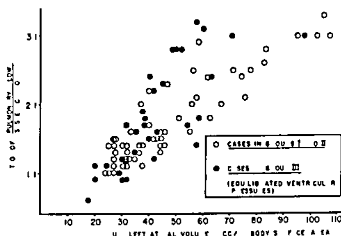


Fig 3 The relationship of left atrial size to the degree of left to right shunt present in cases of isolated ventricular septal defect

long axis of the left ventricle, it is necessary to calculate its long diameter by stereometry The maximum volumes of the two chambers were chosen as the reference points for three reasons (1) to minimize the overlap of the chambers, (2) to take advantage of their more perfect elliptical shape during late diastole, and (3) as logically this state should accurately reflect increased volume loads An ECG, recorded simultaneously with the angiocardiogram with the moment of each exposure denoted, was employed in determining the maximally distended state Some cases had to be discarded because of the chance absence of an exposure in the proper phase of the cardiac cycle

The angiocardiograms of 15 cases of mild pulmonary valvular stenosis of the same age group, with gradients of no more than 30 mm Hg at rest, were examined to obtain normal values for the left atrial and ventricular volumes measured by this technique All volumes were related to the patient s body surface area as estimated by height and weight in order to make the numerical values comparable throughout the age group involved, 23 ± 7 ml/m² of body surface was the mean and standard deviation obtained for the left atrium, and 83 ± 20 ml/m², for the left ventricle

The left atrial volumes of the ventricular septal defect series plotted against the calculated ratio of pulmonary to systemic flow and against the peak systolic pulmonary artery pressure are presented in Figs 3 and 4 Similar plottings were obtained for the left ventricular volumes and showed the same trends with somewhat less definition The percentage of cases in the groups, classified as previously described and demonstrating left atrial enlargement, is presented in

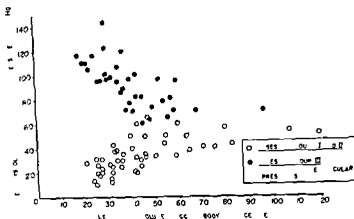


Fig 4 The relationship of left atrial size to the degree of pulmonary hypertension present in cases of isolated ventricular septal defect

Fig 5 A similar presentation of left ventricular volumes, combined with the ECG data is seen in Fig 6

The electrocardiograms uniformly consisted of standard leads unipolar extremity leads unipolar extremity leads and chest leads from V_{4R} to V_7 The method of ECG interpretation is not within the scope of this paper but follows the general criteria proposed by SOKOLOW (1949) A comparison by groups of the size of the left ventricular chamber against the ECG evidence of left ventricular hypertrophy is also presented in Fig 6 It should be noted, however, that despite 50 cases with correlation between the size of the left ventricular chamber and ECG evidence of left ventricular hypertrophy, both being positive or negative there were 25 cases with possible or definite evidence of hypertrophy with a normal ventricular volume and 5 cases with dilatation of the ventricular chamber without ECG evidence of hypertrophy ECG evidence of right ventricular hypertrophy was present in none of the cases in group I, in 40 % of the cases in group II and uniformly in the group III cases

Fifty of the 80 cases in the series were selected for conventional roentgen examinations in close connection with their angiocardiographic studies The films consisting of lateral oblique and routine and penetrated frontal views of the chest with barium in the esophagus were examined by six observers with 3 to 10 years experience in pediatric cardiovascular radiology The fact that this was a group of ventricular septal defect cases was known The observers on each of four separate occasions were asked to evaluate the left atrial size, left ventricular size degree of left to right shunt and degree of pulmonary hypertension Each of the four parameters were graded on a scale of four according to the following scheme

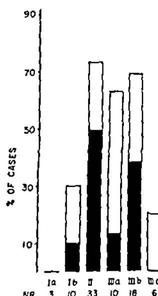


Fig 5 The incidence of left atrial enlargement in 80 cases of isolated ventricular septal defect grouped by catheterization data Left atrial volume measured from angiocardiogram | between 2 and 3 standard deviation above the normal left atrial volume ■ more than 3 standard deviation above the normal left atrial volume

Left atrial size was judged by the left atrial chamber volume with the wall thickness assumed to be constant normal = normal mean ± 2 standard deviation (9 to 37 ml/m²), questionably enlarged = 2 to 3 standard deviation above the mean (38 to 44 ml/m²), definite enlargement = 3 to 4 standard deviation above the mean (45 to 51 ml/m), massive enlargement = more than 4 standard deviation (more then 51 ml/m²)

Left ventricular size was assessed by a combination of left ventricular volume and wall thickness as indicated by the ECG

	ECG evidence of		
	No hypertrophy	Questionable hypertrophy	Definite hypertrophy
Normal mean ± 2 SD (43 to 123 ml/m²)	Normal sized	Questionable enlargement	Definite enlargement
2 to 3 SD above (124 to 143 ml/m²)	Questionable enlargement	Questionable enlargement	Definite enlargement
3 to 4 SD above (144 to 163 ml/m)	Definite enlargement	Definite enlargement	Massive enlargement
More than 4 SD (more than 163 ml/m²)	Massive enlargement	Massive enlargement	Massive enlargement

(Standard deviation abbreviated to SD)

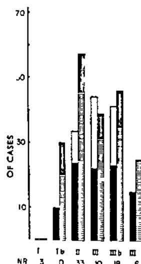


Fig 6 The incidence of increased volume and hypertrophy of the left ventricle in 80 cases of isolated ventricular septal defect grouped by catheterization data Ventricular volume measured from angiocardiogram □ between 2 and 3 standard deviation above the normal ■ more than 3 standard deviation above the normal Ventricular hypertrophy determined by ECG criteria ques tionable = definite

Left to right shunt size was estimated by the ratio of pulmonary to systemic flow calculated from the oximetry data

No left to right shunt = a ratio of 1 1 or less
Questionable shunt = a ratio of 1 1 1 to 1 2 1
Definite shunt = a ratio of 1 3 1 to 2 1
Massive shunt = a ratio of more than 2 1

The degree of pulmonary hypertension was estimated by the peak systolic pulmonary artery pressure against the peak systolic systemic pressure which was estimated where it was not simultaneously recorded The cases were divided into four arbitrary groups

No pulmonary hypertension = pulmonary up to 1/4 systemic
Mild pulmonary hypertension = pulmonary 1/4 to 1/2 systemic
Moderate pulmonary hypertension = pulmonary 1/2 to 3/4 systemic
Marked pulmonary hypertension = pulmonary pressure more than 3/4 systemic

The pooled results of the observers who participated in this experiment are presented in the Table on p 24 It was interesting to note that in 12 of the cases the left atrium was enlarged more than 4 SD and the mean accuracy of the 6 observers was lowest in judging these massive volumes, these largest atria were considered from the conventional films to be questionably enlarged in 21 % and normal in size in 16 % of the evaluations No such freaks in error distribution were found in left ventricular shunt or pressure assessments

Table

Accuracy in the assessment of left heart size and the degree of left to right shunt and pulmonary hypertension in 50 cases of isolated ventricular septal defect (6 observers examining only ordinary films)

	Left atrial size	Left ventricular size	Left to right shunt	Pulmonary hyper tension
Mean percentage of correct answers				
1 Cases less than one year of age (13)	21	35	50	22
2 Cases 1 to 16 years of age (37)	52	44	43	48
3 All cases (50)	44	41	45	41
Range of percentage of correct answers — all cases	23—52	32—50	32—56	32—52
Mean percentage of answers within ± 1 grade of the correct answer — all cases	76	72	82	81
Range of percentage of answers within ± 1 grade of the correct answer — all cases	66—80	68—78	72—98	70—94

The assessment of the roentgenologic accuracy in judging pulmonary vascular resistance, which is one of the basic problems in ventricular septal defect, is hampered both by the lack of a good method to measure pulmonary vascular resistance in infants and children, and a satisfactory means mathematically to express pulmonary vascular patterns The cases with high pulmonary vascular resistance associated with pulmonary hypertension, as diagnosed by clinical, catheterization and angiocardiographic data, were examined Three pulmonary patterns, examples of which are illustrated in Figs 7, 8 and 9, were encountered

Discussion

The catheterization data, which form the basis of the estimation of the degrees of shunting and pulmonary hypertension and upon which the method of classification employed depends, are subject to error Anesthesia, lack of a stable metabolic state, and streaming of columns of oxygenated and unoxygenated blood are some of the factors which contribute to this error These problems are perhaps accentuated in infants, and the relatively large number of infants in group III b (11 out of 18) may account for the distortion of this group from the expected findings so far as left atrial volume and ECG evidence of left ventricular hypertrophy are concerned (Figs 5 and 6) With a more ideal method of classification the distribution of the findings in groups III a and III b might well be reversed

Errors are also present in the method employed to estimate the chamber volumes of the left atrium and ventricle The more dilated these chambers, the more nearly they conform to an ellipse, thus the larger the chamber, the more



Fig 7 High resistance high reserve or fetal pattern of pulmonary vascular resistance in an eight year-old female with a pulmonary artery pressure of 110 53 against an aortic pressure of 110 65 mm Hg and a ratio of pulmonary to systemic flow of 0.5 1 at rest

accurate the determination by this method There is some overlap of the left atrial and ventricular volumes with the mitral valve bulging into the base of the ventricular ellipsoid and no compensation was made for this error The rate of exposures during left heart filling in this series was either 2 or 6 paired exposures per second which despite ECG correlation leaves the likelihood of obtaining an exposure in the true maximally distended state open to some question Lastly the basic shape and the more regular contours of the left atrium make its measurement and volume determination by this method intrinsically more accurate than those of the left ventricle ARVIDSSON has estimated the theoretical accuracy of this method of determination of left atrial volume to be within ± 8 % DODGE et coll (1960) using human post mortem specimens concluded that the method results in an over estimation of the left ventricular volume in the region of 15 %

The heart rate at least at the extremes of range can probably influence maximum chamber volumes by altering the diastolic filling time The inability to investigate fully the magnitude of this influence with the material available and the size of the normal series leaves the statistical validity of the normal values open to some doubt however these values perhaps may serve as a first approximation of normality as measured by this technique

Despite these limiting factors inherent in the methods used it is apparent that in infancy and childhood gross heart size generally correlates with the degree



Fig 8 A transitional pattern of high vascular resistance in an eleven year old male with a pulmonary artery pressure of 99/56 against a systemic pressure of 110/67 mm Hg and a pulmonary to systemic flow ratio of 1 2 1 at rest The peripheral arterial oxygen saturation dropped from 97 % to 78 % with exercise

of left to right shunt as estimated by oximetry This relationship appears less certain in cases with equalized left and right ventricular pressures The left atrial and ventricular volumes also reflect the degree of left to right shunt and probably with greater over all accuracy than does gross heart size

A correlation may also be suggested between gross and left heart size and the degree of pulmonary hypertension, but as the pressures come into the range of systemic pressures, this relationship breaks down The variance may be explained, for with peak systolic pulmonary artery pressures in the range 60 mm Hg in children — perhaps slightly lower in infants — further increases in pressure are apparently dependent upon increased pulmonary resistance This level corresponded to approximately 45 mm Hg mean pulmonary artery pressure which correlates well with the results of SWAN et coll (1954) who found 50 mm Hg mean pulmonary artery pressure to be the level above which the calculated pulmonary vascular resistance is significantly increased The increased resistance at a high pressure is such that there is no left to right shunt and therefore the real problem of the heart is one of outflow obstruction to the right ventricle and not an excess volume load These dynamics result in an hypertrophied right ventricle with a normal or small sized left heart and relatively smaller total heart size than is associated with large left to right shunts

Accuracy in judging left heart size from conventional films would appear to be more likely in children than in infants However, an over all absolute ac

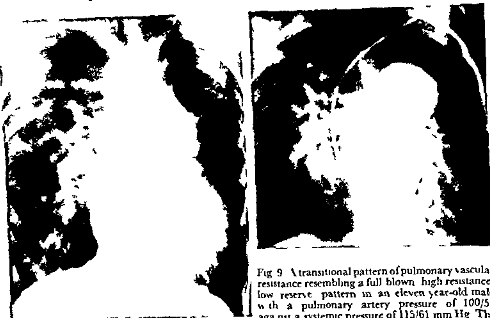


Fig 9 A transitional pattern of pulmonary vascular resistance resembling a full blown high resistance low reserve pattern in an eleven year-old male with a pulmonary artery pressure of 100/53 against a systemic pressure of 115/61 mm Hg The ratio at rest of pulmonary to systemic flow was 2 1 but with exercise the peripheral arterial oxygen saturation dropped from 93 to 77 Hemivertebrae in the upper thoracic spine account for the scoliosis

curacy approaching 50 % in assessing left atrial and left ventricular size on a scale of four, combined with an accuracy within one grade in the range of 75 % indicate that the technique is capable of clinically useful accuracy in cases of isolated ventricular septal defect

It is probable that the reason for the unexpected errors in judging massively enlarged atria was the tendency of some of the observers to down grade long smooth esophageal displacements in the presence of a gross heart enlargement The enlarged left atrial appendage evident in the frontal views of these cases was either overlooked or disregarded

The degree of left to-right shunt may be estimated in ordinary films with a slightly higher accuracy than in the assessment of the sizes of the individual left heart chambers by the same technique

The existence of roentgenologic appearances bearing a relationship to the various clinical and pathologic states found in association with pulmonary hypertension and isolated ventricular septal defect was pointed out by DAMMANN & FERENCZ (1956) In the 2 month to 16 year age group included in the series the roentgenologic vascular patterns encountered in association with pulmonary hypertension and *increased* pulmonary vascular resistance seem

to correspond to the pathologic groupings of such lung vessel changes as outlined by EDWARDS (1957).

A fetal, or 'high resistance high reserve' pattern resembles pathologically the normal fetal vascular pattern. There is marked prominence of the muscular medial layer and some increase in the thickness of the elastic laminae in the muscular arteries and arterioles associated with an apparent constriction of these vessels. These pathologic appearances of the pulmonary vascular tree probably correspond to those depicted roentgenologically in Fig. 7, in which there is a narrowing of the pulmonary arteries, except perhaps the main pulmonary artery. *There is normal 'tapering' present at the branchings.*

A secondary or 'high resistance low reserve' pattern indicates obliterative changes in the intima of the large muscular arteries and similar obliterative changes in the dilated thin walled small muscular arteries. These obliterative lesions are credited with giving origin to the characteristic blunted or 'pruned' configuration at the branchings of large muscular arteries that may be evident in roentgenograms. This pathologic entity undoubtedly corresponds to the roentgenographic appearances described in association with congenital heart disease by KEATS et coll. (1956), DOYLE et coll. (1957), EVANS & SHORT (1958) and STEINER et coll. (1961).

Fig. 9 *illustrates a late transitional pattern with many of the features described with this entity* including dilatation of the proximal part of the pulmonary arterial tree, an abrupt diminution in caliber at the tertiary and quarternary branchings ('pruning'), and narrowing of the peripheral branches.

A transitional pattern has been described as combining a variable mixture of the findings of the fetal and secondary types. Figs. 8 and 9 probably represent two far separated examples. Fig. 8 demonstrates slight dilatation of the large pulmonary arteries with some increase *tapering at the tertiary and quarternary* branchings. Fig. 9 illustrates a case of a transitional pattern of the lung vessels resembling a full blown 'high resistance low reserve' pattern.

The roentgenologic appearances suggested as representing the pathologic 'high resistance high reserve' pattern of EDWARDS are usually found in cases of marked pulmonary hypertension during infancy, and the 'high resistance low reserve' pattern is characteristic of pulmonary hypertension of long standing in adult life. However EDWARDS has seen a case of pulmonary hypertension with the fetal pattern in a 37 year old subject and has observed a transitional or 'high resistance low reserve' pattern in a two year old infant. WAGENVOORT et coll. (1961) have reported two cases in which early transitional changes were present at 11 and 27 days of life.

Due to the difficulty in distinguishing by routine roentgenography the fetal and certain transitional patterns of high resistance from vasculature with normal resistance the only consistent conventional *film criteria of pulmonary* hypertension in the pediatric age group is the discrepancy between left and right heart sizes. The recognition of a transitional or frank 'high resistance

low reserve pattern is good evidence of pulmonary hypertension but its occurrence in infants is the exception rather than the rule

The over all absolute accuracy in judging the degree of pulmonary hypertension on a scale of four was 41 % with an accuracy within one grade of correctness of 81 % The absolute accuracy was 22 % in cases less than 1 year of age against 48 % in those above this age This difference in accuracy probably reflects the difficulties encountered by the roentgenologist in distinguishing the high resistance high reserve pattern commonly present in pulmonary hypertensives during infancy as well as in judging left heart size in this age group

Conclusions

The volume of the left atrium is a reliable index of the pulmonary flow in isolated ventricular septal defects Gross heart size and left ventricular chamber volume generally correlate but are perhaps less sensitive indicators Conventional roentgenographic assessment of left atrial size left ventricular size and the degree of left to-right shunt, is capable of clinically useful accuracy Individual chamber assessment appears relatively inaccurate during the first year of life

Gross heart size left atrial and left ventricular volumes bear a complex relationship to the degree of pulmonary hypertension In milder cases of hyper tension the correlation is a positive one but as the pulmonary artery pressure approaches systemic levels, further increases in pressure are associated with a diminution in the magnitude of the three parameters The total relationship is more evident with the left heart than with the total heart volume

The estimation of the degree of pulmonary hypertension from routine examination of the pulmonary vasculature in children is complicated by the existence of more than one pattern of increased pulmonary vascular resistance and by the difficulty in the differentiation of the fetal and transitional patterns from vascular trees with normal or increased flows without increased resistance The conventional film estimation of the degree of pulmonary hypertension by the integration of the appearance of the heart and the pulmonary vasculature is inaccurate during the first year of life but in the older subject may reach clinically useful accuracy

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SUMMARY

The conventional film appearances gross heart size, left atrial and left ventricular chamber volumes ECG findings, and cardiac catheterization data were studied in 80 cases of isolated ventricular septal defect examined in infancy and childhood The correlations between the roentgen appearances and the physiologic state are outlined and discussed

ZUSAMMENFASSUNG

Achtzig Falle von isoliertem Ventrikelseptumdefekt des Sauglings und Kindes wurden im Hinblick auf das Herz Lungenrontgenbild die Herzgrosse die linken Vorhofs und Kammer volumina Ekg und Katheterisierungsbefunde untersucht Beziehungen zwischen der Rontgenanatomie und dem physiologischen Befund werden aufgezeigt und besprochen

RÉSUMÉ

Quatre vingts cas de communication interventriculaire isolée chez des nourrissons et des enfants on été examinés en considérant l image radiologique ordinaire le volume total du cœur celui de l oreillette et du ventricule gauche l ÉCG et les résultats du cathétérisme cardiaque Les rapports entre l anatomie radiologique et l état physiologique sont étudiés et décrits

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Fig 1 2 year-old boy with acute abdominal pain fo 6 hours no vomiting Conventional roentgenography Intussusception with apex in transverse colon (group I) confirmed by barium enema and reduced



Fig 2 2 1/2 year-old boy with abdominal pain for 3 hours Conventional roentgenography Proximal colon almost empty of gas soft tissue mass present (group II) reduced

Terms such as cupola, crescent phenomenon bicycle seat bird s beak conical stenosis and coil spring are encountered in the literature and can hardly be justified If gas in the colon is demonstrated during the examination it should be described as such and not as often happens as radiolucency Descriptions of appearances in roentgenograms in terms of shadows may be misleading It would appear to the writer that the following may be regarded as the principal characteristics of intussusception

1 A soft tissue mass at the site of the intussusception this is best demonstrated when outlined by gas the tip of the intussusceptum is often demarcated by gas in the bowel

2 An abnormal distribution of gas the proximal part of the colon contains unusually little gas while gas containing widened loops of ileum sometimes tapering off to a cone before they enter the intussusceptum may be evident

3 Mechanical ileus which is usually due to intussusception in these cases

The roentgenograms often show more than one of these three signs so that the diagnosis is strengthened

There is general agreement that conventional roentgenography is indicated in all probable cases of intussusception A film taken with the beam horizontal should also be included

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CONVENTIONAL ROENTGENOGRAPHY IN DIAGNOSIS OF INTUSSUSCEPTION IN CHILDREN

by

Hjalmar Bolin

*The purpose of conventional roentgenography in cases of probable intus*susception used to be to exclude or confirm the presence of mechanical ileus It has since been claimed, however that conventional roentgenography may demonstrate characteristic signs of invagination (Solis Cohen & Levine 1938 Williams 1940, Levitin 1941, Nordentoft 1961), several illustrative examples *have been published by Hellmer (1948) Jackson (1953) described 4 cases of* intussusception diagnosed by conventional roentgenography Middlemiss (1955) reported a series of 62 cases, 75 % of which had signs of mechanical ileus, a fifth of the latter also exhibited evidence of intussusception, as did also the remaining 25 % The series thus contained no normal cases It should be mentioned that the data *this author gave on the duration of the* symptoms were incomplete, it varied between 1 and 5 days in the 8 cases illustrated According to Frimann Dahl (1960), ordinary films often afford adequate evidence for an exact diagnosis, though the findings may vary over a wide range, from nearly negative findings to fully developed acute obstruction

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Table 1

Classification of cases according to findings in conventional films and barium enema investigations

Conventional films		Barium enema			
		Intussusception		No intussusception	
Positive					
group I		63		2	
group II		74		19	
group III		38	175	4	25
Negative			53		396
	Total		228		421

Negative No signs of intussusception in conventional films The negative group included those cases that were regarded as roentgenologically normal These included many with strikingly little gas in the digestive tract and others with the intestines filled with gas, but not distended as may be seen in meteorism in crying children

The cases are classified in Table 1

The duration of symptoms and the number of operations and deaths among the 228 cases with verified intussusception are given in Table 2

Of the 228 cases in which the barium enema indicated intussusception conventional films of the abdomen disclosed signs of the condition in 175 (77 %)

Obstruction of the small intestine was demonstrated in groups I and II but only in 38 cases (III) was the condition dominated by ileus This group differs from the other two by the obviously longer duration of symptoms and much higher frequency of surgical intervention and by the fact that most of the fatal cases occurred in this group Of the 53 cases in which conventional roentgenography had not revealed signs of the condition the duration of the symptoms had been much shorter than in the 3 positive groups and the intussus-

Table 2

Classifications of cases according to duration of symptoms and number of operations and deaths in 228 cases with verified intussusception

Positive (conventional films)	Less than 6 hour history	More than 24 hour history	Number of operations and deaths out of total number of cases in the groups: Operations	Deaths
group I	29	26	9/63	1/63
group II	35	32	9/74	0
group III	0	72	24/38	7/38
Negative (conventional films)	38 °	23	6/53	1/53



Fig 3 16 month old male infant with abdominal pain for 2 days vomiting and bloody stool Conventional roentgenography Mechanical obstruction of small bowel (group III) intussusception could not be reduced Operation revealed a Meckel s diverticulum forming the apex

Material

In an attempt to assess the diagnostic value of this type of examination, the writer has reviewed all cases of probable intussusception examined by conventional roentgenography and barium enema during the years 1934—1961 The material from 649 cases was available and consisted of 423 boys and 226 girls aged from 3 months to 13 years In 228 of these, of which 155 were boys and 73 girls, a barium enema confirmed the diagnosis of intussusception and 80 % of these were reduced by the enema The conventional and contrast films were re examined independently of one another and the former films were classified according to the above mentioned characteristics

Results

Positive Signs of intussusception in conventional films

I Definite evidence of intusussception in cases in which the intussusceptum could be located (1), possibly combined with (2) and (3) (Fig 1)

II Typical roentgenogram of intussusception (2), possibly combined with (3) (Fig 2)

III Roentgenogram strongly suggesting intussusception and dominated by loops of the small intestine distended with gas and fluid (3) (Fig 3)

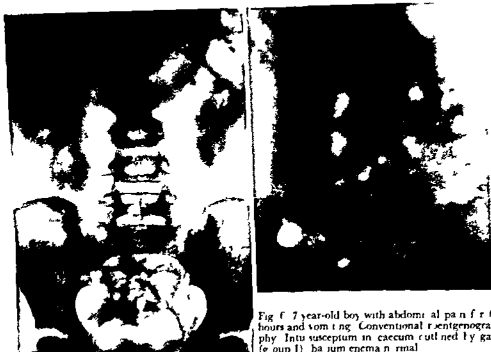


Fig f 7 year-old boy with abdomi al pa n f r f hours and vom t ng Conventional roentgenography Intu susceptum in caecum outl ned by gas (g oup I) ba ium enema n rmal

The barium enema was normal in 421 cases However, a review of the conventional films of the e cases disclosed conclusive signs of intussusception in 25 (6 %) It may be concluded from this that the barium enema was responsible for the false negatives The case records of those 421 cases were also studied for evidence of bloodstained stools, a palpable mass and edema of the ileo cecal valve A note was also made of those cases in which it was found impossible to fill the terminal ileum with contrast medium (These

Table 3

Number of cases with other signs of intussusception among the 25 cases with positive conventional films b t negative barium find ngs as compared with the 396 double negative cases

	The 25 positive cases with negative barium enema	The 396 double negative cases
Blood stools	6	37
Palpable lump	4	18
Swoll n valve	12	7
No contrast med um in ileum	4	7
	26	64



Fig 4 2 year old girl with abdominal pain for 3 days Conventional roentgenography Proximal colon formed a round mass terminal ileum distended by gas and drawn up with a tapered end reduced



Fig 5 [illegible] year old boy with abdominal pain for 3 hours Conventional roentgenography Intussusceptum in the ascending colon but not involving the caecum confirmed by barium enema reduced

ceptum had, as a rule, been situated in the proximal part of the colon In 50 of the 63 cases, the intussusceptum position was identical (±10 cm) in the conventional and contrast enema films In 6 cases, the intussusceptum was proximal, and in 6 cases distal to the site indicated by barium In only one case of a very mobile intussusceptum was the position significantly different

Conventional roentgenography will generally not show the specific type of intussusception There were however exceptions to this rule The shape and position of the invaginating part of the bowel occasionally indicated that the proximal part of the colon (Fig 4) was also included in the invagination (ileo colo colic intussusception) In other instances the intussusceptum was situated distally to a normal caecum (ileo (ileo) colic intussusception) (Fig 5) No true intussusception of the small intestine (ileo ileal intussusceptum) was diagnosed roentgenologically

As mentioned previously, only films of satisfactory quality were accepted for the present investigation However, during the 28 years covered by the material considerable advances have been made and the percentage of positive conventional roentgenograms during the latter half of the investigation period was consequently much higher than during the first half, as shown below

1934—1947 Of 130 cases of intussusception, 83 were positive (64 %)

1948—1961 Of 98 cases of intussusception, 92 were positive (94 %)

disappeared spontaneously or been unrecognized during the period of the enema cannot altogether be excluded This is exemplified by the 25 cases in which intussusception had been excluded by a barium enema but in which the conventional roentgenograms (and other signs) indicated the diagnosis Conventional roentgenography may thus sometimes confirm a clinically probable intussusception not demonstrable at the barium enema examination

The clinical signs are atypical in certain cases of intussusception and examination of the abdomen reveals no signs of the condition These cases may be referred for conventional roentgenography, and an examination by an experienced roentgenologist will establish the diagnosis The present study has shown that of the 649 cases of probable intussusception two thirds appeared to be normal Consequently if the clinical evidence is doubtful i e if there are no definite signs and conventional roentgenography discloses no indications of intussusception a barium enema is unnecessary provided the child is kept under close observation

SUMMARY

Six hundred and forty nine cases of probable intussusception examined by conventional roentgenography and barium enema were reviewed in order to assess the value of the former method Conventional roentgenography employed with the proper technique would appear to be accurate in 90 of cases The small but important group of 10 of cases in which the findings were negative is discussed in detail

ZUSAMMENFASSUNG

Sechshundertneun und vierzig Falle von wahrscheinlicher Darminvagination wurden mit einfachen Leeraufnahmen und mit Kontrasteinlauf untersucht und die Resultate verglichen Korrekt vorgenommene Leeraufnahmen führten in 90 ° der Falle zum Ziel Die kleine aber bedeutende Gruppe von 10 in denen die Leeraufnahme versagte wird im Einzelnen analysiert

RÉSUMÉ

L auteur a étudié six cent quarante neuf cas d invagination intestinale probable examinés par radiographie simple et par lavement baryté dans le dessein de juger la valeur de la première de ces méthodes Il semble que la radiographie simple exécutée avec une technique appropriée donne un d agnostic exact dans environ 90 des cas L auteur étudie en détail le groupe petit mais important de 10 des cas ou cet examen est reste negatif

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Fig. 7. 5 year old girl with abdominal pain for 6 hours, palpable mass present. Conventional roentgenography: Absence of gas in caecum and proximal transverse colon (group II), barium enema normal.

cases were then examined by barium meal in order that a small unrecognized intussusception should not be overlooked.) The frequency of these signs is shown in Table 3.

Cases of intussusception in the group in which the barium enema had been negative are demonstrated in Figs. 6 and 7.

The investigation has shown that in cases of intussusception conventional roentgenography often discloses such characteristic signs that a positive diagnosis is possible in 90 % of the cases adequately examined. In the remaining 10 % of cases, this type of examination gives no information, the films presenting evidence only of meteorism or normal conditions. It is clear then that it is both wrong and dangerous to believe that the possibility of intussusception may be eliminated by means of conventional roentgenography in spite of the absence of any or all of the signs. The only certain means of excluding intussusception is an examination with a barium enema with retrograde filling of at least 20 cm of the terminal ileum. Even then the possibility of the intussusception having

disappeared spontaneously or been unrecognized during the period of the enema cannot altogether be excluded This is exemplified by the 25 cases in which intussusception had been excluded by a barium enema but in which the conventional roentgenograms (and other signs) indicated the diagnosis Conventional roentgenography may thus sometimes confirm a clinically probable intussusception not demonstrable at the barium enema examination

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Six hundred and forty nine cases of probable intussusception examined by conventional roentgenography and barium enema were reviewed in order to assess the value of the former method Conventional roentgenography employed with the proper technique would appear to be accurate in 90 of cases The small but important group of 10 % of cases in which the findings were negative is discussed in detail

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L auteur a étudié six cent quarante neuf cas d invagination intestinale probable examinés par radiographie simple et par lavement baryté dans le dessein de juger la valeur de la premiere de ces méthodes Il semble que la radiographie simple exécutée avec une technique appropriée donne un diagnostic exact dans environ 90 % des cas L auteur étudie en détail le groupe petit mais important de 10 % des cas ou cet examen est resté négatif

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COMPARATIVE ANGIOGRAPHIC AND RADIOISOTOPIC STUDY OF THE VERTEBRO BASILAR CIRCULATION

by

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The problem of localization, in cerebral vascular disease constitutes the major limiting factor in cerebral blood flow studies as changes in the blood flow in specific regions may not be reflected in values obtained for the brain as a whole (SOKOLOFF 1961) Such changes may be more marked when the circulation is investigated in circumscribed cerebral areas such as those perfused by each of the extracranial afferent arteries

The circulation in the areas supplied by the carotid vessels has been studied by the intracarotid injection of a gamma emitting, non diffusible tracer and by the continuous external recording of the radioactivity in the cerebral and neck vessels (FAZIO et coll 1963) This method affords data on the circulation times and an index of blood flow in these vessels (FIESCHI & DI PIETRANTONJ 1961) The diagnostic tests that have been developed for the vertebro basilar circulation are less satisfactory than those for the carotid circulation The only methods at present available consist in the angiographic demonstration of the vessels (MONIZ 1933) or the recording of changes in the EEG produced by digital carotid compression and forced rotation of the head (BAUER et coll 1961) Two of us (FIESCHI & GARELLO 1961) have injected radioalbumin into the vertebral artery in an effort to obtain hemodynamical data by means of external

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Table

Mean values of the graphic elements of the curves of radioactivity recorded from two cranial and one tho
are divided in three groups accordin

Vertebral angiography		Number of cases	Mean age	A P max/min	Occipito lateral tracing					
					Injections	Time of increment	Time of stasis	Intermediate time	Slope r	Time of decrement
Normal	mean SD	9	45	138/77	12	1′.4 ± 0.6	2.7 ± 0.6	5.5 ± 1	0.417 ± 0.05	8.1 ± 1.1
Slight alterations	mean SD	7	56	159/96	10	1.4 ± *0.8*	2.8 ± *1.3*	6.2 ± *0.5*	*0.319* ± *0.044*	*10.6* ± 2.2
Marked alterations	mean SD	11	53	166/106	17	1.7 ± 1	3.5 ± 1.1	*7′.1* ± 1.4	*0.233*[1] ± 0.07	10.4 ± 2

Values in italics denote difference from group I statistically significant ($p < 0.05$)
[1] denotes difference from group II statistically significant ($p < 0.05$)

recordings The purpose of the present paper is to describe the method used and to present the data obtained, comparing the results with those obtained with vertebral angiography

Method All patients received premedication and were examined in prone position with the forehead resting on a pad Following local infiltration with procaine, the vertebral artery was punctured percutaneously with an angiography needle by a suboccipital approach at the level of the first cervical vertebra (Di Marzio 1956, Ramella & Rosadini 1960) Three scintillation counters were placed in contact with the patient in the following positions

A Occipito lateral, with the major axis directed laterally and slightly anteriorly,

B Occipito sagittal, with the major axis directed toward the external occipital protuberance,

C Thoracic, with the major axis directed to the left paravertebral region at the level of the heart

The detectors employed were 1 crystals, recessed 6 cm, with wide angle collimators with an opening of 5 cm, each counter was connected with a ratemeter The time constant of the integrators was 0.2 seconds for the cranial units and 0.75 seconds for the cardiac unit graphs were obtained by pen recorders at a speed of 1 cm/sec

The dose of radioactive material (radioiodized serum albumin, RISA) varied between 30 and 50 microcuries, depending on the body weight and was dissolved in about 0.5 ml physiologic saline, the injection was manually performed as quickly as possible in under half a second

The injection of radioiodized serum albumin was repeated twice in 14 cases in order to check the values obtained

Table *cont*

racic detectors after the injection of a single dose of radioalbumin into the vert bral artery The patients to the an iographic findings

Occip to-sagittal tracing (inion)						Cardiac tracing		
Injection	Time of increment	Time of stasis	Interm time	Slope "r	Time of decrement	Injections	Vert-cardiac minimum time	Time of cardiac increment
11	1 8 ± 0 9	1 5 ± 0 6	4 6 ± 0 5	0 408 ± 0 075	9 1 ± 1 9	13	5 4 ± 1 1	8 5 ± 1.3
7	2 ± 1 1	2 4 ± 1 4	6 4 ± 1 4	0.298 ± 0 038	9 4 ± 2	9	7 7 ± 1 8	9 6 ± 3 5
11	1 8 ± 0 9	2 8 ± 1 1	7 9 ± 2 3	0 241 ± 0 08	9 9 ± 2 9	15	6 9 ± 2 1	11 3 ± 3.2

Following this procedure vertebral angiography was carried out through the same needle site About 6 ml of triodate contrast material (Hypaque) were injected Three roentgenograms were taken with a manual seriograph in each of two successive exposures postero anterior and lateral

Evaluation of the isotopic curves Two almost simultaneous cerebral curves were recorded in each study (unit A and B) A thoracic curve, beginning some seconds later was also recorded (unit C)

The cerebral curves consist of a single wave which is composed of three phases (1) increment of radioactivity representing the arrival of the tracer (2) a plateau representing the major concentration of the tracer, (during this phase the blood mixed with tracer is redistributed within the cerebral circulation from the arteries to the veins), (3) a decrement of radioactivity during which the tracer flows out of the head

The following time elements are obtained increment stasis and decrement The interval between increment and decrement of the curve at the midpoint of the maximum vertical axis, was also measured and is referred to as intermediate time

The tracings are transcribed on semilogarithmic scale and a single exponential decrement is seen in most cases Its slope is expressed by the exponent r calculated from the semilogarithmic graph as $\frac{1}{T\,0\,37}$ (FIESCHI & DI PIETRANTONJ 1961) This value represents the rate of renewal of the blood in the vascular area perfused by the tracer It is therefore a non linear index of cerebral blood flow in the vertebro basilar area (the ratio between blood flow and blood pool FAZIO & FIESCHI 1960)

The thoracic curve shows a rise of radioactivity followed by an irregular decrease. The measures obtained are: (1) interval between the beginning of the occipito-lateral curve and the cardiac curve itself (vertebro-cardiac minimum time), (2) duration of the increment of the cardiac curve (time of cardiac increment).

Evaluation of the angiography. The diagnostic assessment of the angiographic picture was based on generally accepted criteria (KRAYENBUHL & YASARGIL 1957, YASARGIL 1962, SALAN & ASTENGO 1962). The following aspects, graded according to presumed progression, were studied: (1) reflux of contrast in the cervical tract of the vertebral artery, (2) length, caliber, and regularity of the lumen of vertebral and basilar arteries, (3) appearances of the peripheral branches and of their area of distribution (inferior, middle, superior cerebellar and posterior cerebral), and their morphological features.

On the basis of these elements we have attempted to estimate the presence and degree of vascular changes in individual cases. This part of the study was carried out by the radiologist of our group (A. S.) without any knowledge of the clinical diagnosis or of the results of the isotopic study.

Results

Twenty-seven cases were investigated by the method described. The results can be conveniently divided into three groups, according to the presence and degree of arteriosclerotic changes shown by vertebral angiography. All patients in group I had a completely normal angiogram, all in group II had slight but significant alterations, and all in group III had marked changes in their angiograms.

Group I (Fig. 1). Nine cases had completely normal angiograms. Their age ranged from 21 to 54 years, with a mean of 45. They had no signs of cardiovascular disease, and had normal blood pressure (average 138/77). The clinical diagnoses included peripheral nervous system disease (3 cases), convulsive disorder (2 cases), aneurysm of the anterior communicating artery (2 cases), chronic cerebellar involvement of undetermined nature (2 cases).

A typical isotopic tracing is shown in Fig. 1. The mean values (see Table) are very close to those obtained in the normal young subjects previously studied (FIESCHI & GARELLO 1962). Completely normal tracings were obtained in 8 cases including the patient with chronic cerebellar disease in which a vascular involvement of the posterior circulation could then be almost certainly excluded.

In the 9th case (a female of 51 years) the occipito-lateral curve showed a semilogarithmic slope of 0.31 and a time of decrement of 10.5. The occipito-

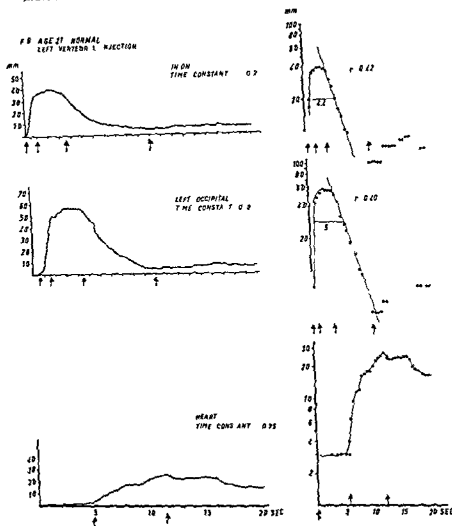


Fig 1 Isotopic tracings in a normal subject

sagittal curve showed a semilogarithmic slope of 0 28 and a time of decrement of 12 These values are slightly abnormal when compared to the normal range (mean ± 2 S D)

Group II (Figs 2 and 3) In seven cases the following angiographic abnormalities were noted parietal filling defects limited to a portion of the arterial trunks (6 cases) tortuosity or elongation of the vertebral (2 cases) or the basilar artery (4 cases) dilatation (4 mm 1 case) or narrowing (1 5 mm 2 cases) of the basilar trunk tortuosity and irregularity of the caliber of some peripheral branch (6 cases) inadequate peripheral regional vascularization (3 cases)

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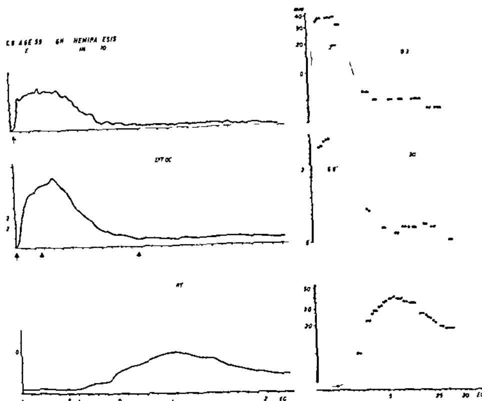


Fig 3 Same case as in fig 2 isotopic curves Moderate reduction of ipsilateral slope and increase of the time of cardiac increment

The ages ranged from 23 to 72 years with a mean of 53 The average blood pressure was 166/106 Ten patients had clinically diagnosed cerebrovascular lesions 3 in the carotid area 2 in the area of the posterior circulation and 5 with multiple localizations In 3 of them the arterial pressure was over 200/120 and electrocardiographic abnormalities were present in 6 cases

One patient (a girl of 23 years) had brain stem involvement clinically diagnosed as multiple sclerosis She was normotensive and was without apparent vascular disease

Compared to the mean values of the first group the following time elements of the isotopic curves showed a significant increase intermediate time and time of decrement of the occipito lateral curve time of stasis and intermediate time of the occipito-sagittal curve time of increment of the cardiac curve Both the semilogarithmic slopes were significantly slower than in the control group (cf Table)

The isotopic tracings in this group showed values which were more abnormal than in the second group but only the mean values of the semilogarithmic slope of the occipito-lateral curve were significantly different

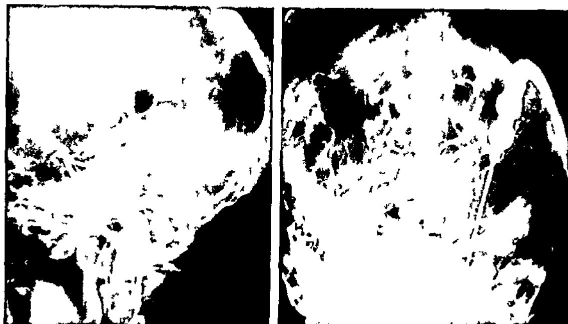


Fig 2 Vertebral angiography Slight arteriosclerosis

The ages ranged from 49 to 62 years, with a mean of 56 Electrocardiographic changes and clinical signs of cardiovascular disease were present in 4 cases One patient was hypertensive (205/130) The average values of blood pressure for the group were 159/96 The clinical diagnosis was cerebral vascular disease in 6 patients (in 5 the lesion was localized to the carotid area, in one in the brain stem) and chronic subtentorial lesion of undetermined nature in one patient (a male of 57 years)

The mean values of the isotopic curves (cf Table) showed increase of the time elements, indicating a slower circulation, and a decrease of the semilogarithmic slopes Significant differences from the mean values of the first group were shown by the semilogarithmic slope and the time of decrement of the lateral tracing, by the intermediate time and the semilogarithmic slope of the sagittal tracing, and by the vertebro cardiac minimum time In no patient was a recording obtained that was within normal limits

The agreement between radiologic and isotopic tests points to an impairment of the posterior circulation, also in the patient with an unclear clinical diagnosis

Group III (Figs 4 and 5) In all patients, marked vertebral angiographic abnormalities were found Parietal filling defects, tortuosity and elongation of vertebral and basilar arteries were present in all The basilar trunk was dilated in 3 cases (more than 4 mm) and narrow in 2 cases (1 5 mm or less) The peripheral branches showed in every case an increased tortuosity and dilatation or narrowing of the lumen A defective filling of a peripheral territory was present in 4 cases

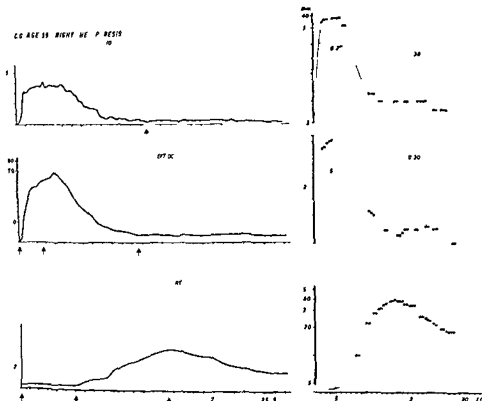


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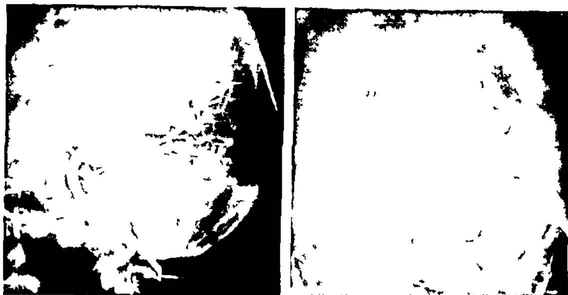


Fig. 4. Vertebral angiography. Marked sclerosis with plaques in the vertebral artery; dilatation, elongation and irregularity of the lumen of the basilar artery.

Discussion

The results presented have stressed the relationships between the functional abnormalities of the posterior circulation shown by the isotopic test and the morphologic alterations of the vessels shown on angiography. Other factors, apart from vascular pathology, can influence the brain circulation. We have tried to control these factors by excluding patients with the following conditions: cardiac decompensation, pulmonary insufficiency, diabetic acidosis, myxedema, anemia, polycythemia, increased intracranial pressure, alterations in the state of consciousness, impairment of intellectual functions not attributable to vascular damage but suggestive of senile dementia. In these conditions modifications of the cerebral blood flow have been demonstrated (Sokoloff 1959, Lassen 1959). Thus it is likely that in our cases the regulation of cerebral hemodynamics was almost exclusively dependent on the effects of vascular pathology on tone and caliber of the blood vessels and on their capability to respond to the homeostatic chemical or neurogenic control mechanisms (Sokoloff 1959, Kety 1960).

The use of angiography for evaluating the degree of pathologic vascularity is not entirely satisfactory. The sensitivity of the method is limited to macroscopic alterations. These alterations could be present in the arteries from the aorta to the site of injection, which are not shown in the angiograms. The alterations are quantitatively and qualitatively different from case to case, and differently distributed. Thus evaluation of the 'degree of involvement' of the whole area is approximate and subjective. By using only three broad categories (normal angiograms, slight alterations, marked alterations) and an independent

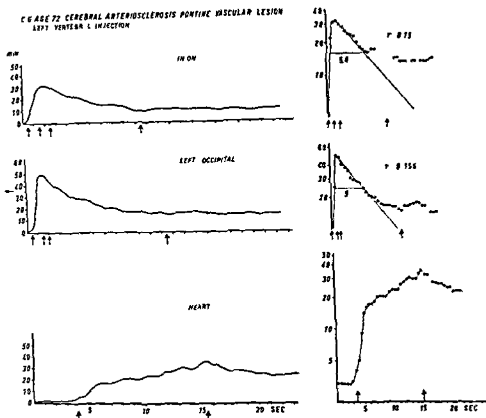


Fig 5 Same case as in fig 4 isotopic curves Marked reduction of the semilogarithmic slopes and retardation of the time of cardiac increment

judgment of the radiologist, we feel that our evaluation of the angiograms is reasonably valid

The isotopic technique has been used extensively for studying the circulation in the carotid areas The general discussion of its validity reported for those studies also applies to its use in evaluating the posterior circulation (FAZIO et coll) Some limitation is encountered in the measurement of the time elements of the curves The duration of the phase of increment may be influenced by the position of the needle in the artery, by small differences in the speed of injection and by possible reflux of the indicator in the cervical part of the vertebral artery The limits of the static and decrement phases are not always sharp and sometimes are identified somewhat arbitrarily (Fig 3) The cardiac curve can be influenced by the position of the detector with respect to the heart and great vessels The duration of each phase is usually different in the two simultaneously recorded cerebral tracings The detectors are placed in

different positions with respect to the area perfused by the tracer: the different geometry leads to a different influence of various sections of the circulation on the two tracings, and can explain the differences of the curves. However the total duration of the two cerebral curves is always very similar.

The semilogarithmic slope has comparable values in both tracings. Therefore it can be considered as an expression of the functional aspects of the whole vertebro basilar circulation. The mean value of 0.41 in the control group suggests that in normal conditions the blood in this area is renewed completely about every 2.2 seconds or 27 times every minute. We do not know the normal values of the rate of blood flow or size of blood pool in this area, but this figure is probably too high. The method may overestimate a fast component of the circulation, or the mixing of the tracer with blood may be incomplete due to laminar flow. Judging from the homogeneity in the control group, and from the existence of significant variations in the pathologic states, the 'intermediate time' and the semilogarithmic slope appear the most reliable and sensitive indices of hemodynamic impairment.

Alterations of the isotopic curves were found in every single patient with angiographic abnormalities. In most cases there is a close correlation between the results of the two tests. The variations of the mean values from the control group to the group with slight angiographic changes are greater than the further variations encountered in the group with more marked angiographic changes. In group III the mean value of the slope is reduced to 56 % of the controls. Without considering possible errors and variations in the blood pool, this means that in patients with advanced arteriosclerosis in the vertebro basilar area the blood flow is nearly half of the normal.

Clinical signs of cerebral vascular disease were always accompanied by pathologic aspects of angiographic findings and the isotopic curves. Both studies generally showed greater alterations in patients with parenchymal damage in the area of the posterior circulation (all but one such patient is included in group III). Even in vascular disease with signs of parenchymal involvement limited to the carotid area, alterations in the posterior circulation of the same degree as those of the previous group may exist. These alterations, on the average, are less marked (five patients with this diagnosis are included in group II, three patients in group III).

In two patients with chronic subtentorial syndromes, the comparable results obtained with the two tests helped the clinical diagnosis. In one patient without apparent vascular disease and with normal angiography, the isotopic test showed a discrete hemodynamical damage: the age (51 years) and the presence of brain pathology could account for this finding (SOKOLOFF). In one young patient with diagnosis of multiple sclerosis, both tests have shown a high degree of involvement of the posterior circulation: we have no explanation of this result, unless an error of diagnosis can be assumed.

In three patients with vertebro basilar circulatory insufficiency, vertebral

angiography performed by direct puncture of the artery at the moment of the injection of the contrast medium caused disturbances of consciousness, respiratory alterations and serious vegetative phenomena These complications were of short duration and without any apparent after effect They nevertheless underline the existence of contra indications The injection of 0 5 ml of saline containing the nuclide on the other hand has been in all cases completely innocuous The isotopic test by itself can also be given with a smaller needle (FIESCHI & GARELLO 1961) The technique described appears therefore a safe and useful method for the study of dynamical alterations of the vertebro basilar circulation

Acknowledgement

This study was supported by a grant from the Consiglio Nazionale delle Ricerche

SUMMARY

The vertebro-basilar system was investigated by the vertebral injection of gamma-emitting isotopes and percutaneous recording in 27 cases 9 of which were normal and 18 had evidence of arteriosclerosis The isotopic curves demonstrated progressive hemodynamical alterations in the latter The technique may be a useful diagnostic aid in the clinical study of vertebro-basilar circulatory disturbances

ZUSAMMENFASSUNG

Das vertebro-basilare Gefässsystem wurde mittels vertebraler Injektion von gammastrahlen den Isotopen in 27 Fallen untersucht 9 Falle waren normal und 18 litten an Arteriosklerose Die erhaltenen Isotopenkurven zeigten in den letzteren Fallen progressive Storungen Die Methode erscheint von diagnostischem Nutzen fur die Erforschung der vertebro-basilaren Gefassstorungen

RÉSUMÉ

Le système vertébro-basilaire a été étudié par injection dans l artere vertébrale d isotopes émetteurs gamma et par enregistrement percutane dans 27 cas dont 9 étaient normaux et 18 présentaient des signes d artériosclérose Les courbes isotopiques ont montré des altérations hémodynamiques progressives dans ces derniers cas Cette technique peut compléter utilement l étude clinique des troubles circulatoires vertébro-basilaires

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PERCUTANEOUS SPLENIC VENOGRAPHY UNDER ROENTGEN TELEVISION CONTROL

by

O ARNER and I FERNSTROM

Percutaneous splenic venography may involve a danger of serious and sometimes fatal complications Intra peritoneal haemorrhage is said to be the commonest sequela and is thought to be due to the spleen following the respiratory movements and being injured by the puncture needle The writers replaced the conventional instrument by a needle fitted with a polythene catheter in order to obviate this complication After puncture of the spleen the needle is withdrawn and the contrast medium injected through the catheter (FERNSTROM 1955 SELDINGER 1957)

Percutaneous splenic venography has been performed during the last two years under roentgen television control with the apparatus described by EDHOLM FERNSTROM LINDBLOM & SELDINGER (1962) with improvement of the procedure A critical analysis of the results achieved in a series of 200 cases suggested that the method involved less danger of intra peritoneal haemorrhage than the technique previously used in percutaneous splenic venography and prompted its description in greater detail

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Table 1

Complications occurrin at percutaneous splenic venography in a material of 200 cases

	Number of cases
Pyrexia up to 38 C for 4 days	36
Pyrexia up to 38 C for 7 days	3
Pyrexia up to 40 for 4 days	4
Severe abdominal pain for 2 days	5
Signs of severe intraperitoneal haemorrhage	1
Minor pneumothorax or pleural effusion	2
Complications occurred in a total of	51 cases

greater assurance and without undue haste Moreover the catheter could be left in the spleen when the position of the patient was changed Percutaneous splenic venography was carried out in two different positions at one session in 15 cases 12 patients being examined supine and prone and the other 3 cases supine and lateral

Percutaneous splenic venography was performed under roentgen television control in 106 cases in 85 of these the spleen was not enlarged but in 6 of these 85 cases the examination was unsuccessful owing to the catheter slipping out of the spleen during the injection of the contrast medium on four occasions and due to failure of the puncture on two occasions

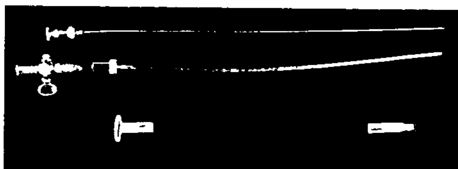
Thirty millilitres of Urografin 60 % were injected within 3 seconds in 137 cases and in the remaining 63 cases 50 ml within 5 seconds injection of the latter amount of medium resulted in better filling of the splenic and portal veins and an improvement in the quality of the hepatogram No untoward effects were observed

The contrast medium was injected by hand in 176 cases whereas in 24 cases an automatic pressure syringe was used to inject 50 ml of contrast medium within about 5 seconds No untoward sequelae resulted from the use of the latter

Complications referable to the examination per se occurred in 51 cases (25 %) the majority of these were however mild in character (Table 1)

Thirty six cases were pyrexial for four days and 3 for seven days 4 cases had a high temperature for 4 days one had severe abdominal pain and 2 cases presented evidence of pleurisy which regressed spontaneously Clinical signs of intra peritoneal haemorrhage were observed in only 1 case As these complications regressed spontaneously laparotomy was not required in any case

The primary condition required laparotomy in 108 cases The operation was performed within one to six days after the venography in 47 of these cases (Table 2) and disclosed intra peritoneal haemorrhage in 2 of them in one of these latter cases laparotomy four days after the procedure revealed the presence of 300 ml of blood in the peritoneal cavity It is interesting to note



The instrument *Top* needle *Middle* catheter with nut and screw portion *Below* end of the catheter which fits into the adapter (left) and the tip of the catheter (right)

Material The series comprised 200 cases examined by percutaneous splenic venography in the years 1955 to 1960, 87 being women and 113 men The spleen was not enlarged in 158 cases All the cases were carefully followed up after the examination with special reference to possible complications of the procedure In 109 cases laparotomy was carried out within 1 to 60 days of the procedure, the operator being asked to make a special note of evidence of intra peritoneal haemorrhage

Method The technique used in this investigation has been described earlier (SELDINGER 1955, EDHOLM et coll 1962) It should however be pointed out that the demonstration of the ventral intrahepatic veins or of the left main branch of the portal vein may sometimes be unsatisfactory in the position that was then described An additional examination should therefore be carried out without withdrawal of the catheter with the patient prone or in the lateral position A further 5 ml Urografin 60 % are injected under roentgen television control, the position of the tip of the catheter being checked on the monitor screen The film changer is then brought into position without the patient being moved and the examination repeated Percutaneous splenic venography was never performed more than twice at any one session in any of the cases of the present series

Results

The polythene catheter was left in the spleen for 10 to 60 minutes Puncture of the spleen was successful and satisfactory positioning of the tip of the catheter was achieved at the first attempt in about half the cases in the remaining cases several punctures were required The spleen was however never punctured more than six times at one session in any one case

The position of the catheter was not affected by respiratory movements or by a change in position of the patient — with exception of a few cases in which the catheter slipped out of the spleen during the injection of contrast medium or exposure of the films — which enabled the procedure to be performed with

cent of the cases in this series an incidence that is practically the same as that observed among cases examined by the conventional method (without a catheter)

Abdominal pain and symptoms and signs of pleurisy have also been observed following the procedure These sequelae also occurred in the present series As no previous data on their incidence are available, no firm conclusions can be drawn concerning the value of the technique described in lessening these dangers

The quantity of contrast medium recommended in the literature varies between 20 and 80 ml (GVOZDANOVIC et coll 1955 WANNAGAT 1956 ANACKER et coll 1957 1959 BOURGEON PIETRI DAUMAZER, PANTIN & CATALANO 1957 PASKE et coll 1959 and others) The injection of 50 ml contrast medium had no untoward effects in the present series, it was found that the administration of this amount of medium improved the quality of the films

The general opinion appears to be that 10 ml contrast medium should be injected by hand within one to two seconds Some authors consider that the use of an automatic pressure syringe involves risks (WANNAGAT 1956 ANAKAR et coll 1957, and others) while others favour its use (BOURGEON et coll 1955 STEINER et coll 1957) We are inclined to recommend it first because it enables the rate of injection to be standardized and secondly because the roentgen dose delivered to the operator is greatly reduced

It was found that the use of stereo angiography facilitated the identification of any collateral veins present

The performance of percutaneous splenic venography under roentgen television control proved to have several advantages (1) blind puncture of the spleen is eliminated because the spleen and the puncture needle are seen on the monitor, (2) the position of the catheter within the spleen may be easily checked on the monitor during the injection of the contrast medium and this facilitates examination of a spleen of normal size

It is generally held that puncture of a spleen of normal size presents difficulties Percutaneous splenic venography was unsuccessful in only a few such cases of the present series and then usually because the catheter slipped out of the spleen during the injection of the contrast medium or exposure of the films and not because of failure when puncturing

A further advantage of the method of examination described is that it may be performed in a fully illuminated room with consequent improvement in the precautions to ensure asepsis

SUMMARY

The use of a soft polythene catheter for injection of contrast medium in percutaneous splenic venography was found to lessen the danger of the complication of intra peritoneal haemorrhage Two hundred cases are analysed Roentgen television control of the procedure facilitated the puncture of spleens of normal size as well as the proper positioning of the catheter

Table 2

Findings at laparotomy performed one to six days after percutaneous splenic venography

	Day after injection					
	1st	2nd	3rd	4th	5th	6th
Absence of intraperitoneal haemorrhage in number of cases	6	8	3	7	12	9
Presence of intraperitoneal haemorrhage in number of cases	1*	–	–	1**	–	–

* Small quantity of blood
** About 300 ml blood

that the haemorrhage caused no clinical signs Only a small quantity of blood was found at operation in the second case In the 61 cases in which laparotomy was performed within seven to sixty days of the examination, a small quantity of blood was evident in the peritoneal cavity in 6 cases The incidence of severe intra peritoneal haemorrhage producing clinical signs was 0 5 per cent in the series

Discussion

Minor intra peritoneal haemorrhage is frequently found at laparotomy performed shortly after percutaneous splenic venography (GVOZDANOVIC & HAUPTMANN 1955, EVANS & O SULLIVAN 1957, BRUWER & HALLENBECK 1957, FIGLEY 1958 and others) STATTIN (1959), however, in a small series comprising 6 cases, in which operation was performed two to five days after the procedure, encountered this complication only in one case According to ANACKER, DEVANS & LINDEN (1957), HEITZMAN & RIGLER (1957), BERGSTRAND & EKMAN (1957), STEINER, SHERLOCK & STEINER (1957), FIGLEY (1958), PANKE, BRADLEY, MORENO & RUZICKA (1959), ANACKER (1959), and BERGSTRAND (1961) major intraperitoneal haemorrhage, endangering the life of the subject, occurs in 1 to 2 per cent of cases

Several workers have stressed the importance of avoiding major injury to the spleen at splenic puncture to lessen the risk of intra peritoneal haemorrhage Repeated puncture of the spleen, repeated injection of contrast medium at one session, and prolonged retention of the puncture needle in the spleen are all said to increase the danger of intra peritoneal haemorrhage (BERGSTRAND et coll 1957, ANACKER 1959) Several splenic punctures were performed and a number of injections of contrast medium were made at one session in this series, moreover, the catheter was left in the spleen for quite a long time Nevertheless, intra peritoneal haemorrhage occurred in a remarkably small number of cases This suggests that the use of a polythene catheter for injection of contrast medium involves less danger than a puncture needle

Pyrexia may occur following percutaneous splenic venography (BERGSTRAND et coll 1957, PANKE et coll 1959) This observation was confirmed in 2 per

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A SIMPLE TECHNIQUE FOR MAKING CASTS OF THE HEART

by

GUNNAR WESTBERG

Access to accurate anatomic casts of the blood vessels and cavities of the heart is often a considerable advantage in cardiac investigations. Such casts may be of assistance both in the selection of the most suitable projections for angiography and in the subsequent interpretation of the films. Anatomic models made of a cold polymerizing plastic substance by the corrosion method are often both detailed and exact, and various techniques for making them have been described, among others by TOMPSETT (1956) and JAMES (1961).

The methods previously described are rather complicated, however, and it appears that good results may be obtained with a simpler and more rapid procedure. One of the most important conditions for success is the choice of a suitable material. The synthetic resins available on the market vary considerably in their properties. The material to be used for the casting should be capable of being quickly prepared, and should not be too sensitive to small variations in the mixing process; if devoid of these properties its viscosity will be unsuitable and the setting process (polymerization) will be unfavourably affected. It should *furthermore* not be subject to shrinkage while hardening and it should be easy to colour.

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ZUSAMMENFASSUNG

Die Anwendung eines weichen Polythenkatheters fur die perkutane Kontrastinjektion in die Milz vermindert die Gefahr einer intraperitonealen Blutung Zweihundert Falle wurden analysiert Der Eingriff ist erleichtert bei kleiner Milz oder wo die korrekte Position des Katheters in Frage steht wenn man Bildverstarker mit Fernseheinrichtung zur Verfugung hat

RÉSUMÉ

Les auteurs ont constaté que l utilisation d un cathéter de polyéthylène souple pour l injection du moyen de contraste dans la phlébographie splénique percutanée diminue le risque de complication hémorragique intrapéritonéale Ils en présentent deux cents cas La ponction des rates de volume normal et la mise en place correcte du cathéter sont facilitées par le controle en roentgen télévision

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Fig 2 Specimen ready for corrosion The metal rods hold the two halves of the heart in their exact anatomic positions

before the cast has set If one of the rods is made extra long it may be used as a stand when the specimen is mounted (Fig 1)

I *Removal and preparation of the heart*

1 The heart is removed together with sufficiently large portions of the afferent and efferent vessels to allow for the attachment of short pieces of plastic tubing It is freed from blood clots by rinsing if it is not to be used at once it may be stored in a frozen condition

2 The afferent and efferent vessels (with the exception of the aorta) are lengthened with short pieces of transparent plastic tubing which are tied on after having first been widened slightly at one end to prevent slipping The free ends of the tubes are provided with corks which fit firmly but can be removed when necessary (Fig 2)

3 The aorta is provided with a piece of rigid plastic tubing which is to serve as the injection syringe (Fig 3) The cork which acts as a piston must be tightly fitted so that no backward leakage takes place when it is pushed in

II *Preparation of the synthetic material*

The amount of plastic material required may be readily estimated by filling the right and the left sides of the heart with water with their plastic tubings attached and then measuring the volume (weight) of the latter The weight

In an earlier paper (WESTBERG 1963), a plastic material of methacrylic resin type, suitable for casts of the vessels and subarachnoid cisterns of the brain, was described in some detail. This substance possesses most of the properties mentioned above, and it may also be used to advantage in preparing casts of cavities as large as those of the heart. It is widely used in dentistry, and may therefore usually be obtained from dental suppliers. The material used by us is called Quick 3 60, but other brands are also available. It is supplied in the form of a powder (polymer) and a liquid (monomer), which only need to be mixed to produce the required blend. The accelerator has already been added to the monomer and the catalyst to the polymer.



Fig. 1. Final cast of [illegible] heart with one of the rods serving as a stand.

The viscosity of the material, and at the same time the setting rate, may readily be regulated by varying the proportions of powder and liquid. It has been found that a mixture of equal parts gives a suitable viscosity and allows the mass to be injected over a period of about 5 minutes, and to harden after half an hour. The mass should be kept cool in a water bath while setting, especially when employed in large volumes such as those required to fill the cavities of the heart. If this condition is not fulfilled the heat evolved as polymerization proceeds may cause the mass to 'boil', in other words it bubbles and expands. Another advantage of suspending the specimen in a water bath is that the risk of deformation will be lessened. Different colourings may be obtained by adding finely pulverized pigment to the polymer (the powder) before it is mixed with the monomer (the liquid). A good colour for the arteries is obtained with cadmium red while Paris blue may be used for the veins. Concentrated sodium hydroxide solution is used for the corrosion work. This has the advantage over the commonly used concentrated hydrochloric acid and sulphuric acid in not emitting irritating gases and consequently not requiring special ventilation; it also has no effect on metal objects in the room.

Apart from the choice of a suitable material, the fixation of the two halves of the heart in the correct mutual relationship after the tissue has been dissolved away seems to present a special problem. This may be solved by passing metal rods, pointed at one end, through the two halves to serve as reinforcements



Fig 4 Back of the heart Bunches of small vein are seen runn ng f om the septum

of the material required will be approximately the same, but the amount should be increased by about 25 % to allow for spilling which can hardly be avoided when the specimen is being filled The heart should then be carefully emptied

1 Equal amounts by weight of polymer (powder) and monomer (liquid) are weighed out separately for the right and left halves of the heart

2 The material is coloured with the finely pulverized pigment, which is mixed with the weighed amount of plastic powder before the liquid is added

3 Immediately before the material is to be fed into the heart the coloured powder is emptied into the liquid and stirred, fairly rapidly but nevertheless thoroughly The material for the right side of the heart is prepared first, the mass for the left side should not be prepared until after the former has been completely filled, owing to the fact that the viscosity gradually increases

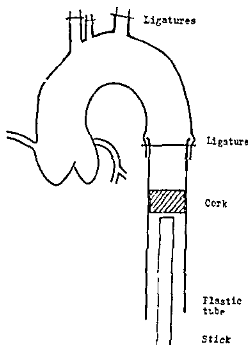


Fig 3 Arrangement for the injection of the aorta

III *Introduction of the material into the heart*

1 *Right atrium and ventricle, and coronary veins* The freshly prepared blue material is poured in through the inferior or superior vena cava after the other afferent and efferent vessels have been carefully closed The whole of the right half of the heart is filled, and the vena cava is then closed Any water and air still remaining in the heart should be allowed to escape by slightly withdrawing and replacing one of the corks If the heart is then squeezed gently, even the smallest coronary veins will fill

The material for the artery side, coloured in advance, is now prepared

2 *Aorta and coronary arteries* The freshly prepared red material is run in through the 'aorta tube', which is filled to the brim The tightly fitting cork is placed in position and pushed down into the plastic tubing with a stick as shown in Fig 3 As healthy aortic cusps close the aortic orifice completely, the material is pressed out into the coronary arteries when suitable 'aortic pressure has been obtained, but owing to the risk of rupture the pressure should not be too high The cork is left in the plastic tubing so that the material sets with the aorta distended



Fig 5 Cast of the heart from below showing the spiral arrangement of the trabeculae in the left ventricle and a small artery branching into the left papillary muscle

3 *Left atrium and ventricle and coronary veins* These are filled with red material As the tubings leading to the left atrium are usually fairly narrow this part of the heart generally has to be filled with the aid of a syringe a wound syringe is suitable and should always be held in readiness

4 Before the material has set the right and left sides of the heart are fixed in their exact anatomic positions This is done by pushing two pointed metal rods (made of copper brass or other suitable material) through the heart (Fig 2) One of the rods may be passed through the aorta and the superior vena cava or the pulmonary artery and the other through the two ventricles in such a direction that no damage will be caused to the larger coronary vessels If the rod through the ventricles is made sufficiently long its bent portion may be used as a stand for mounting (Figs 1 and 2)

IV *The setting process*

The heart is suspended hanging freely in a bath of cold water The setting process will then take place at a slower rate (about 1 to 2 hours)

the adequacy of the shadow as a visual stimulus However these factors are not the sole determinants of the effectiveness of the roentgen shadow as a visual stimulus and more important the vast majority of the shadows we fail to perceive are perfectly adequate visual stimuli They are overlooked because of other factors which affect the perceptual process — Concern over contrast and unsharpness to the total exclusion of all other factors which affect perception does not therefore seem reasonable Because it is possible to measure contrast and unsharpness with ease we have become unduly concerned with the control of these factors The real criterion of the usefulness of a roentgenogram is the likelihood that a radiologist who views it will arrive at an accurate diagnosis There has never been any evidence to suggest that unsharpness expressed in millimeters (an unphysiological measurement) and contrast measured between the lightest white and the blackest black (an equally unphysiological measurement) correlate well with the likelihood of accurate diagnosis

We might perhaps ask ourselves if quality as we commonly know it, is the aesthetic beauty of a film rather than its diagnostic usefulness

Developments

No sooner did the first roentgenograms appear than the first radiologic evaluation of image quality developed It was appreciated that these early crude images did not accurately depict either the internal anatomy of the bone or of the soft tissues Since penetration of the bone was then a triumph, demonstration of internal cortical and medullary —and eventually the trabecular bone — patterns became the popular measure of image quality Some radiologists still use these variable and highly subjective criteria with satisfaction

A similar phase of development in astronomy and in microscopy led to somewhat different results The quality of the optical image produced by different lenses was evaluated by astronomers on the basis of ability to separate the bright points of double stars Microscopists observed the periodic parallel ridges on the shell like skeletons of diatoms and used this pattern as a standard method for evaluating image quality Similarly, FOUCAULT over a century ago devised an artificial standard test device (or phantom) consisting of sets of parallel black and white lines of graded width and separation This and similar test objects are still commonly used The term resolving power was later devised by astronomer John Strutt, Lord Rayleigh as the capability of an instrument for recording and distinguishing fine details

But resolving power did not always accurately indicate quality In 1867 DAWES noted a halo of fluff around stars observed by certain perfect instruments while poorer instruments might give a clearer picture A perfect little glass then gave only a single image where the poorer large one accurately showed the double star The rings and fluff about the central bright star were described by AIREY in 1834 and attributed to the light distribution in his lenses This concept of a heap of light high in the centre diminishing at the image edges has come to be known as the spread function of a point source of light This concept has become most important in the development of photo-

diagnostic effectiveness, and every radiologist faced with the purchase of an expensive piece of diagnostic equipment asks himself what he is getting for his money and how the quality of the roentgen image can be evaluated

The perceptibility of the roentgen image and the radiologist s utilization of it are equally important Perceptibility of the details of the image can be numerically evaluated Perceptibility of the image itself and its utilization are more complex problems involving psycho physical methods Elaboration on these methods will not be attempted at this time Since the rays forming the image are ordinarily invisible they must be converted or transformed into light rays which are visible This latter image might be better termed a radiologic image and the former a roentgen pattern

The 'quality' of a roentgen image like the quality of any other image traditionally depends on the faithfulness of its portrayal of the real structure radiographed Since roentgen rays can traverse matter, the appearance of internal structures is sought, and since colour reproduction is not feasible, what we actually see is a sort of caricature of those real structures This caricature is more satisfactory in many ways than a faithful external likeness would be Like most caricatures it tends to portray salient features and sometimes real features more clearly than can be seen in the original structure Examples are found in tomography and high kilovolt techniques The caricaturisation or selectivity factor is one of the aspects of 'image quality' in radiology which is least liable to objective analysis

The important factors contributing to image quality which are more susceptible to measurement are contrast, resolution, grain or noise and exposure Contrast is usually expressed as a percentage of total black or white However there also may be contrast in the invisible roentgen image and either can be expressed as the mean fractional change in absorption of two adjacent areas (JACOBSON) Resolution is the distinctness of detail usually expressed as a maximum number of line pairs per unit of length, or sometimes for a whole field as the total number of lines distinguishable Grain or noise may be considered as random effects of random radiation which detract from the quality of image formation Exposure or exposure dose is the amount of radiation used to produce an image expressed in units of roentgen (r) or milliroentgen (mr)

Definition of image quality

Image quality and its numerical expression are the subject of this discussion and should be defined It could be that our present concept of image quality, like Dawes 'perfect little glass is an imperfect instrument for the job it must do To cite TUDDENHAM

> The essential feature of any roentgen shadow is its capacity to stimulate the retina of the observer If the shadow is an inadequate visual stimulus it will not be perceived and accurate diagnosis is unlikely It is certainly true that unsharpness and contrast determine *in part*

BOUWERS and other early workers on unsharpness considered it the sum of all the various forms of unsharpness These components were not additive, however in that the largest of them contributed relatively more to total unsharpness than did any other component (MORGAN and KLASENS) Even the radiographic image of an opaque knife edge photographically has a graded black to white border, although it may seem abrupt to the eye Scanning this border with a densitometer gives an S shaped curve with a measurable width and gradient These measurements are reflections of the system s ability to form images of high or low quality They assume a sharp flat edge of complete absorption and negligible thickness Actually, of course, thicknesses are finite, absorption is partial edges are irregular and humanly are neither flat nor sharp

If unsharpness is either neglected or stabilised other high contrast test objects may be used, and historically the most sophisticated of these are equivalent line and space patterns which may be read in lines per millimeter We have etched a copper plate with a television screen focussing pattern for this purpose WILLIAMS has illustrated a similar apparatus Six such test patterns were illustrated in a recent report CAMPBELL s device a plastic plate with lead filled converging and diverging grooves appears to be most practical Wire screens (RAMSEY) (LEVY & WEST) silver wire (BERRIDGE & GUEST) copper wire (MATSUDA et coll), tungsten wire (ROSE) coiled wire (MORGAN), converging wires, all have an added edge unsharpness deficiency (SEEMAN) Of these, only Ter Pogossian s and O Loughlin s test patterns took any cognisance of object contrasts

FRANTZELL found that wires of small diameter had an added unsharpness due to their relationship to the larger focal spot His experiments with small drops of mercury showed marked distortion of image as well as added magnification and pseudoscopic unsharpness VAN ALLEN s system of exposing a micrometer adjusted slot in a lead sheet over a moveable screen and film probably holds the fewest errors of these methods The resulting roentgenograms closely resemble the line and space diagrams used by photographers It has not been used in conditions simulating those in clinical practice, although it should not be too difficult to do so Speed and contrast ratings have been studied by this method for fluoroscopic screens photographic apparatus and film screen combinations by MORGAN who found for instance a gamma rating between 1 4 and 2 0 for various photofluorographic systems Detail resolution between 17 5 lines per millimeter and 6 lines per millimeter was noted for Patterson detail screens and Patterson B fluoroscreen Most intensifying screens resolved about 10 lines per millimeter

Until HECHT s work on the physiology of vision stimulated CHAMBERLAIN (1942) there was little attention given by radiologists to advances in the theory of optics or of photographic theory ROSE s contributions to the quantum theory of vision added impetus MORGAN, and STURM applying these ideas to

graphic theory All photographs can be considered organised groups of point sources of varying intensities of light

Artificial stars, bright pinholes, were used in testing lenses for microscopy and photography Resolving power and contrast could be evaluated in this way Using densitometers the point source could be scanned and the spread function transferred to a graph Certain advantages remain in this 'pinhole' system since the amount of energy or light which passes through the hole can be estimated fairly accurately There is evidence that the retina handles all images in the form of circular areas of illumination

In 1822, FOURIER, in his book on heat transfer, proposed a theory of the composition of heat waves which developed wide application in other fields He proposed that heat wave forms of identical shapes (crest and trough) can be represented by a series of simple waves known as 'sines' Each wave of a series has a frequency that is an integral multiple of the lowest or fundamental frequency in the series Size and amplitude depend on the shape of the original wave This principle simplified the study of complex waves, since they could now be treated on individual terms as simple components of waves This theory when applied to the electromagnetic waves of telegraphy developed *into what we now know as 'communication theory'* Communication theory was used in telephony, radio, television and now is popular in photography and psychophysics

In radiography, attempts to arrive at objective methods of quality evaluation historically began, as we have noted, with the use of dried bone as a subject, and progressed through incandescent lamp filaments and other opaque mis *cellany to wire meshes of various dimensions In general these images* could aid in evaluating intensifying screen contact and resolving power, but it was difficult and often impossible to express this evaluation quantitatively ALBERS *SCHONBERG studied off focus radiation by these methods* BRONKHORST's addition of a step wedge and Luft s star pattern were somewhat more sophisticated attempts at quality standardization, but again, these methods did not have *good numerical representation*

'Sharpness' of image was obviously important but 'unsharpness became its expression because it was easier to measure and its component parts could be more easily *analysed 'Unsharpness was defined as the width of the image* boundary (black to white) in millimeters Acutance, which includes a density scale factor, became its photographic expression

Component contributions to unsharpness were

1 Film screen unsharpness (film unsharpness was relatively so small as to be insignificant) (MORGAN)

2 *Geometric unsharpness — due to finite size of the roentgen source* (HODGES)

3 Motion unsharpness (WILSEY)

4 *Absorption or anatomical* unsharpness (SEEMAN)

a detectable structure from its surroundings BURGER (1936) early appreciated the relationship of contrast and resolving power Since they are not the same kind of quality they cannot be summated or compared directly (SEEMAN) Furthermore, when contrast nears or reaches 100 % this relationship is not apparent Incidentally high contrast techniques are less popular in radiology today because it is believed that more information is available with high kilovoltage methods (TUDDENHAM) JACOBSON objects to this trend He says that if one calculates the amount of information per dose one finds that there is one wavelength only where maximal information is obtained and that this does not often lie in the high kilovoltage regions Screens and films are now designed for high kilovoltage techniques and also with a view to reduction of exposure dose Indeed, such success has been obtained in exposure dose reduction that quantum noise granularity has become a consideration in radiography as well as in image intensification fluoroscopy

BURGER's use of a low contrast (chest type) test phantom made of varying thicknesses of unit density material confirmed for radiologists the close relationship of contrast and definition It also gave them a tool which could be used in the contrast ranges where radiological problems arise Contrast noise and noise detail ratios could be appreciated and contrast detail diagrams became quite easy to construct NELSON devised a similar test phantom CHAMBERLAIN and MORGAN modified the design by adding more rows of appropriate thicknesses of wood or plastic and metals to bring the circular areas up to about 100 % contrast with a background density of 1 0 This principle has also been used by WEBSTER et coll , HENNEY OOSTERKAMP et coll and ARDRAN *et coll* The most recent design modification is a reapplication of this principle to the problem of quantum efficiency and detectivity in photography ZWEIG in 1961 used tiny holes of 3 5 to 160 microns covered by a filter which increased in density by 0 3 (transmittance decreased by 2X) in successive columns Visibility of holes is also determined by the spread function of the system and even more important to the radiologist is directly related to what can be seen by a human observer Perhaps the simplest contrast emergence quality test is the determination of that amount of radiation which will just bring a 2 or 3 mm hole or dot out of its background or just disappear again into background (WEBSTER) A single numerical expression of image quality is an advantage HENNEY expressed quality by the single detail whose depth and diameter are equal and just barely discernible this detail lies on a 45 angle from the abscissa of the Burger test pattern

Contrast detail diagrams have been very useful in the evaluation of performance of image forming systems — particularly since the advent of the image intensification apparatus TOL OOSTERKAMP & PROPER corroborated STURM & MORGAN's calculations experimentally using this technique and also suggested that the minimum contrast fluctuation ratio is 3 rather than 5 as determined by ROSE and by STURM and MORGAN They did not agree with

image intensification systems, predicted a 'scintillation' limit beyond which image amplification could not be successful This unassailable limit has been called 'the minimal permissible dose of X ray exposure (HAY) ROSE constructed an artificial test object according to a graphic formula for an ideal information obtaining system Because a hole of a certain area limited optical information to a calculable amount, and because circular holes were easy to handle, he used a series of holes of varying depths and diameters for his test phantom He used factors of 2 for each step both in diameter and in contrast Of course, the evaluation of 'just perceptible' holes was made by unfatigued men in a comfortable darkened environment A contrast detail diagram resulted for each increment of light Photons were recorded photographically and counted By this means ROSE confirmed earlier estimates of quantum efficiency (signal noise ratio) of the eye as 5 % at adaptation levels and 0 5 % at high levels, with estimated retinal storage time of 0 2 seconds BERGER (1936) had made a similar phantom and appreciated that the relationship of contrast and detail was particularly important at low contrast levels HAY (1958) used the same principles in constructing a somewhat different pattern HECHT s concepts on the probability of seeing were applied by NEWELL to chest radiography (also a low contrast problem) ZWEIG has recently used this method to relate the detecting ability of photographic materials to that of the human eye

Elaboration on the thesis that spread function not only is the intrinsic unit of all photographs but that it reflects the characteristics of the lens, camera and film complex which produce the picture, has led to emphasis on the sine wave response function in photography This system is particularly applicable to the conventional optical test pattern of alternating black and white bars of equal width but with decreasing width from group to group (SCHADE)

Optical square wave patterns, when scanned by an oscillograph or microphotometer, record a sine wave flux pattern which can be subject to Fourier analysis (SCHADE, and COLTMANN)

Various terms for this modulus are contrast transmission function, line frequency response, optical transmission factor, sine wave response factor, or preferably, modulation transfer function

This application of communication theory to television and indirectly to photography by Otto Schade was enthusiastically received Radiological applications using 100 % contrast lead bars were made by SCHOTT, BOUWERS, OOSTERKAMP, and SCHOBER From the point of view of manufacturing engineers, this is a most useful concept for the design and construction of diagnostic equipment Presumably, since sine wave response functions are additive, equipment can be designed to produce a given optical result In expert hands they may also provide a good evaluation of image quality by measuring the area under the curves planimetrically

As high contrast (bone detail) structures were initially used to evaluate resolution, low contrast (chest phantoms) were used to evaluate emergence of

of optics seems to have reached its peak The science of perspective has passed This seems to be the day of visual physiology (and psychology?)

Physiological considerations traditionally are based on principles of optics Studies of visual acuity at high light levels have been facilitated and the results standardised by these methods However our interest lies in the other direction and happily much present day vision research is directed towards threshold and low contrast problems Visual threshold has been found to vary (around 100 quanta) moderately for healthy young people and to be related to visual acuity This relationship is so regular for each individual that some having a higher visual threshold act as if others had a visual filter of a certain quality operating throughout the range of visual illumination If the absolute threshold intensity is increased three times the fingers of one s hand become distinguishable at ten times threshold, the gap in a Landolt ring becomes identifiable This illumination 0 002 quantum per second per rod is comparable with a very dark night sky, 20 000 times threshold (4 quanta per second per rod) corresponds to a bright moonlit sky This is only seven times less than is needed for maximal foveal visual acuity Optimal wavelength ranges from 507 millimicrons for rods to 555 millimicrons for cones at the fovea Parafoveal cones probably participate in moonlight vision

Frequency of seeing at threshold levels is 50 % Slight increments of luminosity raise this percentage dramatically At these levels black and/or white circles are equally visible However at higher levels of illumination white circles were more easily seen (PIRENNE) HECHT and NEWELL have shown that summation of subliminal contrasts contributes to the probability of seeing Size contrast brightness and time are the conventional four variables of visual threshold

Temporal summation of image when present is probably chiefly neural Rhodopsin deactivates in 0 5 milliseconds Although synaptic conduction can be as fast there is evidence that some delay permits reactivation of visual pigments and other delay permits modulation of the impulse The physiologic action time is 0 1 to 0 2 seconds Exposures shorter than this are easier to interpret but do not approximate reality The longer exposures bring in more complex neurologic and psychologic factors

Optical considerations of vision imply the focussing of rays of light into the eye This never occurs in nature but may be built into microscopes and certain image intensification systems In general we see ambient light in an unfocussed state This has a bearing on contour formation and the detection of movement two important items This approach to vision called ecological optics, may become important to radiology

Psychological considerations are almost innumerable Perhaps they begin with that most peripheral portion of the brain the retina As noted previously, foveal vision (entirely cone) requires illumination levels attainable in bright daylight Parafoveal cone vision and mixed rod vision extends below the

COLTMANN's statement that there was no correlation between the theoretical fluctuation limit and observed detail perceptibility (COLTMANN also proposed that the sine wave response factor completely specified the imaging properties of an optical system — as had SCHADE) The most recent estimates of the lower limit for contrast fluctuation ratio is 2 (PIRENNE 1961)

Burger type phantoms have permitted determination of exposure dose both inside and outside the test phantom holes and the correlation of these doses with contrast and detail detectability (JACOBS, and MORGAN 1959) HAY coined the term 'information index' (the reciprocal of contrast X resolution) and noted its relation to exposure dose using this type of phantom In his method, blurring and scatter were made negligible The development of MORGAN's area exposure dosemeter facilitates determination of exposure quanta and correlation with visualised quanta The information index can also be determined on each side of a detector and can thus express the overall performance of the detector or system as the information transfer factor'

Predictability and frequency of seeing In nearly all of these exercises, determinations of the presence or absence of contours or images are made by a jury of human observers In order to make their observations less prejudicial, WEBSTER fashioned a series of plates with holes of varying sizes in various unpredictable positions In this way the observers' results can be analysed as in the conventional contrast detail diagram and also in relation to the number of errors per observation and per observer BURGER's apperception studies are thus brought back to our attention The system of perceptible holes seems most applicable to further psychophysical studies STAUFFER, and HAY, and others have found that for practical purposes two, or at the most three, observers are sufficient To study observer errors, larger groups may be needed

In addition to the above uses, the contrast detail diagram method has been proposed as a tool for the study of the ability of an imaging system to record motion BURGER has arranged his test phantom with a pendulum attachment so that varying excursions can be fairly well maintained In this way blurring due to lag , slow recovery time, cable discharge and other such factors can be measured WEBSTER also has incorporated motion into this system

Alteration of various factors changes the shape of the contrast detail diagram (OOSTERKAMP & ALBRECHT) These effects may become more important if contrast enhancement (GERSHON COHEN) and contrast suppression (MACKAY, and JACOBSON) become more popular Contrast enhancement may lower the curve, and contrast suppression may move it to the right by making the exposure dose more effective Both of these adjustments accentuate the noise segment in the centre curve of the contrast detail diagram

Complicating human factors

Ordinary human vision is not well understood The introduction of radiological considerations may aid or may hinder that understanding The science

mum permissible X ray dose At this time and in this context a major problem is the use of the minimal permissible X ray dose The existence of this quantity has been discussed by all recent contributors While it is basically related to the contrast/detail/noise/exposure problem, its expression is a quality — the diagnostic quality of the image as judged by the radiologist Images of less than diagnostic quality are wasted and do not contribute to the information of the radiologist or the welfare of the patient The exposures used to produce in effective images do however contribute to the radiation load of the patient and his segment of the population Thus, there is a need for determination between the maximum and minimum of exposure doses The optimal exposure is that at which the roentgen image quality is just satisfactory Some radiologists are already working at this level A convenient expression for the optimal combination of factors might increase the number of radiologists using them Image quality could be such an expression

Application of standard tests to diagnostic systems

To one who has seen a television test pattern and has used it to adjust his home television set the desirability of a standard test pattern seems clear What seems less clear is the relationship of picture quality received to the multitudinous factors contributing to its formation transmission and reception Television and information processing in general are under intensive developmental pressures Informal standardisation of techniques and common nomenclature contribute to the industry s rapid development Authoritative standardisation might stifle research and development (MORGAN)

In the case of image quality evaluation in radiology, much the same situation prevails The user wants the engineer and physicist to use techniques and terms which are simple and intelligible He does not want to stifle development or impair accuracy of communication Even if the desired goals are accomplished the tremendous problem of information perception and utilization remains They remain pertinent because image quality bears upon perceptibility and perceptivity As the optical receptors evaluate contours and edges of contrast in a way different from that of the photometer, so we may need to evaluate image quality in a different manner in the light of new psychophysical information Since contrast detail diagrams and sine wave response functions are consciously based on test patterns which are not anatomical there is room for criticism of these methods on this basis Edge absorption (SEEMAN) and tissue mass absorption (JACOBSON) should be included in a more precise system We do not yet know what the limits of such a system are Perhaps more precision is unnecessary or would be confusing or wasted Test patterns can be devised to include edge and tissue absorption

Present day methods for the evaluation of image quality as a complex of line and point spread functions are apparently equivalent Whereas a sine curve response function may be more elegant mathematically contrast detail systems

luminance of moonlight. Rod vision operates down to the threshold of visibility. The process of shifting visual gears from one illumination level to another is adaptation. It is both a retinal and a neural response which acts as does a condenser in an electrical series. It keeps the system in working range so that it can continue to sense small changes at wide ranges of illumination.

At any of the various thresholds insufficient illumination can result in retinal errors in perception. In addition to those previously mentioned (frequency of seeing) positive errors are caused by retinal and personal factors (up to 10 %) and these are aggravated by, among other things, drugs, excessive challenge, dehydration, and fatigue. Occasionally the basic neuronal mechanisms contribute to error.

Every sensation is not transmitted to the brain for judgement. Many are filtered off at the various synaptic levels. Experience probably determines which sensations are suppressed, inhibited, correlated, amplified, or forwarded. Hence training has a great bearing on perception. As we have said before, we do not see as a photometer does. We tend to amplify contrasts, define edges, complete contours, integrate patterns, and abstract concepts. The more basic of these tendencies are neuronal and retinal and are largely unaffected by training. They can be detected. The remainder are largely affected by training and experience. How we look at our world is not entirely haphazard.

'One sees what one knows' — preparation for seeing contributes greatly to the amount of information one can perceive. 'To behold is not necessarily to observe' — the tremendous amount of useless background information available can either overwhelm the beholder, or if he is not wary, it can hide the pertinent information amongst its protective neutrality. Observers must desire to abstract the particularly important bit of information. Here too lies a tendency to err, once having observed a pertinent bit of information his search may be prematurely satisfied.

Cortical integration of received information is too often positive only. Ambiguities are not recognised. It is natural to ask 'What is it that I see?', but we should also remember 'What else could it be?' Eventually, image quality contributes to these questions and to their answers.

Of course, abnormalities of the eye impair image perception. The effect of myopia, presbyopia and astigmatism need not be considered further. Defects in twilight and in dark vision have been very important and still are. Perhaps the loss of translucency of the eye which increases with age (and radiation?) upward from 50 % in the young, combined with the 20 % light absorption (in the young), by rhodopsin may yield an unsuspected decrease in perceptual ability with advancing years.

Conservation of radiation and of population burden

International and national commissions as well as most of the individuals interested in the problem have until now been chiefly concerned with maxi

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are simpler and appeal more to those with a limited mathematical under standing The former system is more adaptable to photometric and semi auto matic methods, *the latter depends on human observation (which is often what we are interested in)* Sine wave response functions are better used where contrasts are high, contrast detail systems where contrast is low

The former is of most help to engineers in the construction of equipment, the latter to the radiologist in testing reactions, aptitudes and training, and equip ment

Both systems reflect image quality, both work Selection of test patterns and methods of evaluation of image quality can be made more simply and more intelligently if there is some prior agreement or standardisation Agreement is preferable to standardisation Contributions, discussions and correspondence are most welcome

SUMMARY

A discussion and review are presented with the intention of providing provocative infor mation initial background and frame of reference for the ICRU sub committee (IV 10) in its preparation of recommendations on methods of measurement of image quality this to enable comparisons to be made of the qualities of the image and speed of the systems

ZUSAMMENFASSUNG

Es wird ein Überblick uber die verschiedenen Methoden gegeben die die Bildqualität be stimmen und die Grundprinzipien die dem I C R U Kommité als Unterlage dienen werden diskutiert Eine Grundlage von physikalis hen und rontgenologischen Einheitsbegriffen fur die Beurteilung der Bildqualität wird vorgeschlagen Die physikalischen Einheiten konnen nach festen Prinzipien bestimmt werden die e werden in der klinischen Praxis durch zahl reiche subjektive Faktoren modifiziert

RÉSUMÉ

Les auteurs étudient et passent en revue les diverses méthodes dans l intention de fournir des données stimulantes une base et un cadre de référence pour la préparation des recom mandations du sous comité (IV 10) de l ICRU au sujet des méthodes de mesure des qualités de l image radiographique pour permettre de comparer les qualités de l image et la rapidité des divers systèmes

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are simpler and appeal more to those with a limited mathematical understanding The former system is more adaptable to photometric and semi automatic methods, the latter depends on human observation (which is often what we are interested in) Sine wave response functions are better used where contrasts are high, contrast detail systems where contrast is low

The former is of most help to engineers in the construction of equipment, the latter to the radiologist in testing reactions, aptitudes and training, and equipment

Both systems reflect image quality, both work Selection of test patterns and methods of evaluation of image quality can be made more simply and more intelligently if there is some prior agreement or standardisation Agreement is preferable to standardisation Contributions, discussions and correspondence are most welcome

SUMMARY

A discussion and review are presented with the intention of providing provocative information initial background and frame of reference for the ICRU sub committee (IV 10) in its preparation of recommendations on methods of measurement of image quality this to enable comparisons to be made of the qualities of the image and speed of the systems

ZUSAMMENFASSUNG

Es wird ein Überblick uber die verschiedenen Methoden gegeben die die Bildqualitat bestimmen und die Grundprinzipien die dem I C R U Kommité als Unterlage dienen werden diskutiert Eine Grundlage von physikalis hen und rontgenologischen Einheitsbegriffen fur die Beurteilung der Bildqualitat wird vorgeschlagen Die physikalischen Einheiten konnen nach festen Prinzipien bestimmt werden die e werden in der klinischen Praxis durch zahlreiche subjektive Faktoren modifiziert

RÉSUMÉ

Les auteurs étudient et passent en revue les diverses méthodes dans l intention de fournir des données stimulantes une base et un cadre de référence pour la préparation des recommandations du sous comité (IV 10) de l ICRU au sujet des methodes de mesure des qualités de l image radiographique pour permettre de comparer les qualités de l image et la rapidité des divers systèmes

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URETHROGRAPHIC STUDIES ON THE POSTERIOR URETHRA

I Motility of the prostatic urethra

by

Olallo Morales, Stig Nilsson and Ragnar Romanus

An earlier paper (24) gave details of the technique of roentgen examination of the male urethra on injection of a highly viscous water soluble contrast medium (Umbradil — Viscous U©) and during active contraction of the pelvic floor with particular reference to motility studies The results in 85 cases were compared with those of concurrent examinations with a low viscosity contrast medium Another paper (25) analysed the anatomy and motility of the boundary area between the anterior and posterior urethra

The motility of the posterior urethra on active contraction of the pelvic floor may be divided into two, usually simultaneous phases (1) elevation of the lower urinary tract and (2) evacuation of the posterior urethra The changes in position and the emptying of the posterior urethra brought about by active contraction may afford information supplementing that of the static films obtained only after the injection of contrast medium This technique makes it

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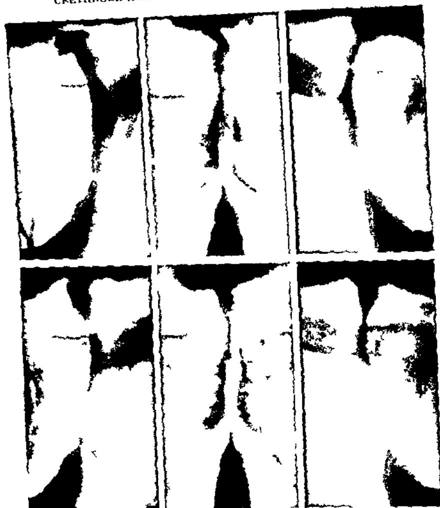


Fig 2 The posterior urethra during injection (upper row) and active contraction of the pelvic floor (lower row) in a healthy subject

collicular relief and expressed the view that if the seminal colliculus *is not* demonstrated *some disturbance* of the normal *motility* is probable

The contrast medium of that period iodized oil owing to its high surface tension did not adhere to the mucosa When the injection was interrupted the iodized oil therefore in a large measure drained away spontaneously, which greatly diminished its value for *evacuation* studies A highly viscous water soluble medium (such as Umbradil *Viscous* U©) adhering well to the mucosa offers however the opportunity for *close* study of the mucosal relief and of the posterior urethral motility *particularly* on voluntary contraction of the pelvic floor



Fig 1 Prostatic carcinoma fixed to the pelvic walls During injection (a) the contrast medium enters only a "new" posterior urethra resulting from deep transurethral resection the internal urethral orifice appears as a small plug in front of the opening of this "new" urethra On straining (b) and micturition (c) no alteration occurs in the position of the organs micturition is thus not dependent upon depression of the pelvic organs Although the function of the trigonal muscle should have been lost owing to the deep resection a broad "micturition funnel" is formed

possible to study the manner in which processes in and outside the genito urinary tract, particularly in the male adnexal glands may influence normal motility

The elevation of the lower urinary tract is considered in detail in the present section while the evacuation of the posterior urethra will be discussed in part II

KOHNSTAM & CAVE (17) pointed out that an urethrographic study of the function of the posterior urethra was greatly facilitated by a film exposed immediately after the injection was completed, in addition to the one obtained during the injection, they did not perform micturition studies In their view, the posterior urethra in normal circumstances was emptied by contraction of the surrounding muscles, while in abnormal conditions, such as strictures, small quantities of contrast medium remained LANGER & WITTKOWSKY (18) and CRUZ (3) likewise expressed the opinion that residual contrast medium in an evacuation film of this type is a sign of disordered function of the urethral and prostatic muscles KNUTSSON (16) studied this reflex evacuation and observed complete emptying of the posterior urethra in normal conditions as well as in the presence of strictures, on the other hand, he noted residual contrast medium in cases without demonstrable genito urinary disorders KNUTSSON stated that 'normal motility is the prerequisite for the appearance of the

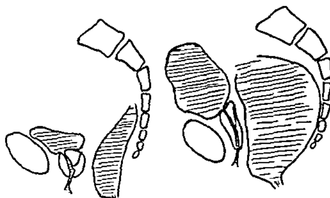


Fig 4 Range of movement of the pelvic organs in different degrees of filling (after CARSON)

The majority of the cases in the series were examined by a general roentgenologist who was familiar with although not specially trained in the technique This affords some insight into its practical application In order further to appraise its value for routine use a series of 280 cases examined with the same technique used as a normal procedure at a roentgen department (Norrköping) was also reviewed the motility studies were found to be satisfactory in 80 %

Types of motility

The normal posterior urethra empties rapidly and entirely on completion of the injection when a low viscosity or non wetting contrast medium is employed This might in part at least be attributed to an increase in tone of the surrounding muscles — a spontaneous evacuation which when a highly viscous water soluble preparation is used is comparatively slow Fluoroscopy shows the contrast column to decrease in width after individually varying periods until the urethra is almost wholly emptied This passive emptying is usually neither so complete nor so uniform as that brought about by active contraction of the pelvic floor When the urethra is distended or not empty, the patient must concentrate a little to combat the involuntary impulse to contract the muscles of the pelvic floor so as not to disturb the evaluation of this passive emptying

A comparison of a film exposed during active contraction (contraction film) with one exposed during injection of the contrast medium (injection film) shows that the contraction empties the diaphragmatic urethra almost entirely of contrast medium the portion corresponding to the external sphincter and the quantity in the prostatic part being also reduced simultaneously the bladder floor and prostatic urethra are slightly elevated

If the patient strains down instead of contracting the pelvic floor the pelvic organs are depressed this also reduces the contrast content of the posterior

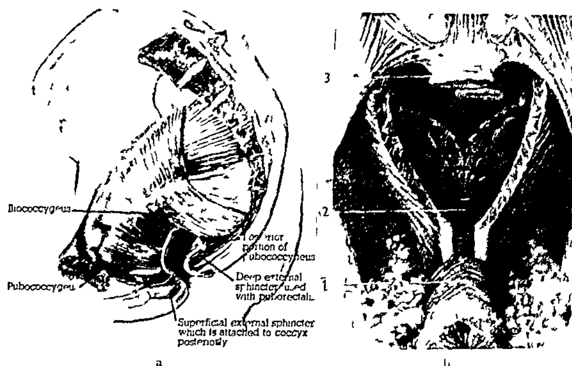


Fig 3 The levator ani muscle (a) from MORGAN (b) from CUNNINGHAM — from behind after resection of portions of superficial muscles sacrum and rectal ampulla 1 — external anal sphincter 2 — dorsal surface of the prostate 3 — rest of sacrum

Technique The physical properties of the contrast medium and the technique of its use have been described earlier (24) The highly viscous contrast material is injected via external urethral meatus under fluoroscopic control and is watched as it passes through the posterior urethra into the bladder Immediately after completion of the injection the patient is instructed to contract the pelvic floor to cut off as if to interrupt urination or hold back flatus drawing the anus upwards When fluoroscopy has shown that the patient understands the procedure a film is exposed of the posterior urethra during injection followed immediately by one obtained during the contraction described (the contraction film) Exposures are made in at least three projections frontal and approximately 40 degrees lateral rotation in each direction A micturition film is also taken when possible in the same projection as one of the rotated views a true lateral view may also be of value

Material One hundred and nine examinations of the posterior urethra were performed in 102 cases (seven were examined twice owing to ensuing clinical changes) It was found on reexamination that the pelvic floor had been correctly contracted in only 65 instances (60 %) These 65 cases were grouped according to diagnoses but as 55 of them had also other disorders the diagnoses mostly consisted of a main and one or more secondary diagnoses (cf part II) The diagnoses were based on clinical examination and in most instances verified at follow up The disorders included chronic non specific prostato vesiculitis (often with acute exacerbations) tuberculous prostato vesiculitis acute or chronic cowperitis benign prostatic hypertrophy prostatic carcinoma (new as well as old cases under treatment with hormones) urethral stricture and conditions outside the posterior urethra but secondarily involving the urethra such as carcinoma or papilloma of the bladder peritoneal carcinosis and sequelae of rectal amputation The series also comprised two wholly asymptomatic healthy subjects

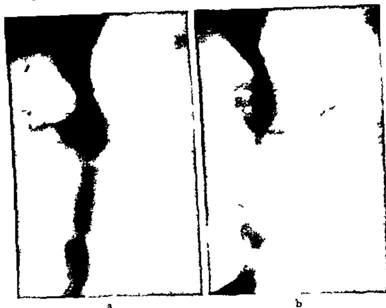


Fig 6 Changes in shape and position of the rectal gas permits assessment of the pelvic floor contraction (levator ani muscles) On comparison with the injection film (a) the contraction film (b) shows the distal plane of the gas in the rectal ampulla to be flattened on pelvic floor contraction while the gas bubble is at the same time elevated more than the prostatic cavity This was a case of prostatic carcinoma treated with surgery and hormones An operation cavity corresponded to the supracollicular portion of the urethra, with a slit running forwards and to the right On voluntary contraction of the pelvic floor the slit emptied completely and a part of the cavity is evacuated probably owing both to pressure of the levator funnel and involuntary reflex contraction of the smooth muscles around the proximal portion of the posterior urethra

gen examination so that satisfactory micturition films were obtained This is said to apply to less than one third of those with hypertrophy or carcinoma of the prostate (according to EDLING only 28 %) Satisfactory films may usually be obtained in micturition however, if a little patience is exercised Since a patient generally has no difficulty in straining during the exposure of a film such roentgenograms may in some measure serve to replace the micturition examination when the range of displacement of the bladder floor and posterior urethra in a distal direction is to be studied

The movement of the prostatic urethra on active contraction of the pelvic floor does not consist solely in vertical elevation nor does the movement brought about by straining or micturition entail only a vertical depression The prostate rotates around a frontal axis in both instances on contraction the prostatic apex together with the adjacent portion of the diaphragmatic urethra are also displaced somewhat ventrally while the base of the prostate

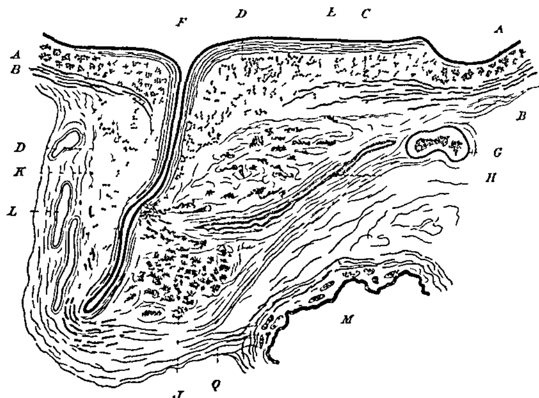


Fig 5 Saggital midsection of the prostate and surrounding structures (after WALKER) A — Circular bundles of bladder muscle B — longitudinal bundles of bladder muscle C — circular layer of bladder neck muscle D — part of the so called internal sphincter E — longitudinal layer of the trigonal muscle F — urethra G — seminal vesicle H — ejaculatory duct J — prostatic gland tissue K — striated muscle on the anterior surface of the prostate proximal portion of the external urethral sphincter near the insertion of the puboprostatic ligament I — veins of prostatic plexus M — rectum

urethra although usually not so fully as the contraction Straining is, however, not a uniform procedure but may be carried out in different ways, as on coughing or sneezing, on defaecation, or as a preliminary to micturition Exposures made during straining are consequently not suitable for routine motility studies although they may occasionally afford information of value

The widening of the proximal segment of the posterior urethra accompanying micturition has been closely studied by several investigators and will not be discussed in any detail in the present paper, the concomitant depression of the pelvic organs has also been previously described, e g by EDLING (5) but disturbances in this mechanism do not appear to have been analysed in detail Such an analysis is possible if the same projection is selected for both injection and micturition films The depression of the pelvic organs is not, however, a prerequisite to micturition (Fig 1) as has been maintained by certain authors, e g MUELLNER (29)

Half the subjects in the present series were able to urinate during the roent



Fig 8 The elevation of the organs is good and according to rule but the evacuation is proportionately poor in a case of widespread prostatic carcinoma Inject on and contract on films The contract on of the sphincter nudae muscle (see earlier paper (23) and the absence of contraction of the external sphincter (nocturnal incontinence) may be noted

These muscles on contraction elevate the pelvic organs But owing to the origin of the medial fibres of the levatores ani muscles from the pubic bone on each side of the symphysis and their dorsal course to the organs and around the rectum (pubo-rectal muscles) a contraction of the pelvic floor will also lead to ventral traction upon the pelvic organs (and a sphincter like compression of the rectum from behind)

The areolar connective tissue between the pelvic organs accounts for their wide range of displacement (Fig 4) Some restraining action is exerted by the pubo-prostatic ligaments which arise from the pubic bone adjacent to the distal portion of the symphysis pubis, close to the origin of the pubo-rectal muscle and are inserted on the central and upper part of the prostate and at its junction with the bladder The ligaments are in this region in close relationship with the detrusor muscle which radiates from the bladder wall to mingle with the muscle bundles around the proximal portion of the urethra The anterior and proximal portions of the external sphincter of the urethra also extend to this area (Fig 5) (Cf also Power (31) Roberts (33) and Kennedy (15)) This striated muscle like the whole of the urogenital diaphragm is connected with the pelvic walls by fairly areolar connective tissue and the chief fixation to the pelvis is effected via the pubo-prostatic ligaments

Contraction of the muscles of the pelvic floor including the external urethral sphincter not only elevates the urogenital diaphragm and the apex of the prostate cranialwards but also draws them somewhat ventrally towards the symphysis This is due to the course followed by the levatores ani muscles and the fixation of the external sphincter by the pubo-prostatic ligaments At the same time the diaphragmatic urethra (= the membranous part) will be compressed by the external sphincter

This mechanism accounts for the relative dorsal tilting of the prostatic urethra on active contraction of the pelvic floor The cooperation of the levatores ani muscles with the external sphincter is clearly exemplified by some cases in the present series in which the ampulla of the rectum was gas filled The contraction films permit comparison of the elevation and altered shape of the rectal gas brought about by the levator contraction with a corresponding effect



Fig 7 The emptying of contrast medium is relatively better than *the elevation of the organs on contraction* of the pelvic floor in a case of adenomatous hypertrophy of the prostate Injection and contraction films

and internal urethral orifice are straightened upwards On straining or urination, the bladder floor and proximal portion of the prostate are depressed to a greater extent than the distal part of the prostate and the diaphragmatic urethra, so that the posterior urethra is seen to 'heel over' backwards as the depression occurs Displacement upwards or downwards will then result in the prostate *in its entirety being tilted as if its apex were anchored to the pubic symphysis* Such elevation with tilting occurred in most cases in the present series ('lifting by rule') (Fig 2)

As the prostate position is shifted the prostatic urethra is emptied of contrast medium, which may result in minor movements being difficult to demonstrate The displacement of the posterior urethra was studied in relation to the osseous pelvis The contours of the posterior urethra and osseous pelvis from the injection films were drawn on transparent material and then aligned with those in corresponding contraction film, this procedure revealed any slight displacement in the urethral outline

A brief recapitulation of certain anatomical details of the supporting tissues of the pelvic floor may aid in a better understanding of the motility

The chief components of the pelvic floor musculature are the levatores ani muscles and the urogenital diaphragm According to investigations by e g MORGAN (27) UHLENHUTH (36) the former are composed of several muscular plates lying both over and behind one another (Fig 3) The lateral and proximal plates form a contiguous hammock like structure while the medial and distal plates (the pubo rectal muscles) lie in a more vertical plane thus forming a funnel The muscle bundles belonging to the levator plate such as the pubo prostatic and pubo rectal prerectal and retrorectal fibres are inserted in the pelvic organs thus positions of which in the pelvis are subject to their action (POWER (31) ROBERTS (33) and others)



Fig 10 Prostatic carcinoma with invasion of the pelvic wall *and perirectal tissues* Fixation of the pelvic floor but not the upper portions of the prostate or bladder Changes in position of the diaphragmatic urethra are impeded while other portions are slightly tilted on straining (b) and particularly on micturition (c) as compared with the *resting position during injection* (a) extra bends develop in a part of the urethra in a portion corresponding to the fixed region

is best demonstrated roentgenographically during micturition when the tone of the levatores muscles and *sphincter is low and the depression* is marked but it is less distinct or imperceptible in the type of straining in which the intra abdominal pressure is increased and the entire pelvic floor and hence the external sphincter as well are contracted (as on coughing or sneezing)

These ligaments in women are inserted on the proximal and central thirds of the urethra and as in men *are in close contact* with the detrusor muscle and the external sphincter *If* the levatores *ani muscles are for* some reason damaged or distended as following delivery the pelvic organs will lie low or will be depressed abnormally far on micturition or straining This will stretch the external sphincter between its attachment to the pubo-urethral ligament and its course around the depressed diaphragmatic urethra Neverth less although at rest the urethral lumen is usually closed a *sudden rise in intra* abdominal pressure on coughing or sneezing will render the sphincter action inadequate and urine may escape a condition known as stress incontinence Jeffcoate (13) *and* Jeffcoate & Roberts (14) have expressed the view that in stress incontinence the *angle normally* present between the almost horizontal bladder floor dorsal to the internal urethral orifice (the trigonal area) and the upper portion of the posterior urethra is almost *straightened out The bladder* in this event will continue directly into the urethra at rest as in micturition This may be due to incompetence *(rupture* or distension) of those fibres of the levatores ani muscles that extend to these areas In women fibres from these muscles are inserted into the antero lateral and proximal portions of the vagina close to the periurethral tissues and *dorsal to the* internal urethral orifice

In normal circumstances when the usual angle between the bladder floor and urethra is present the tone of the smooth muscles around the innermost part of the urethra is sufficient to prevent the escape of urine from the bladder to the posterior urethra at rest A sudden rise

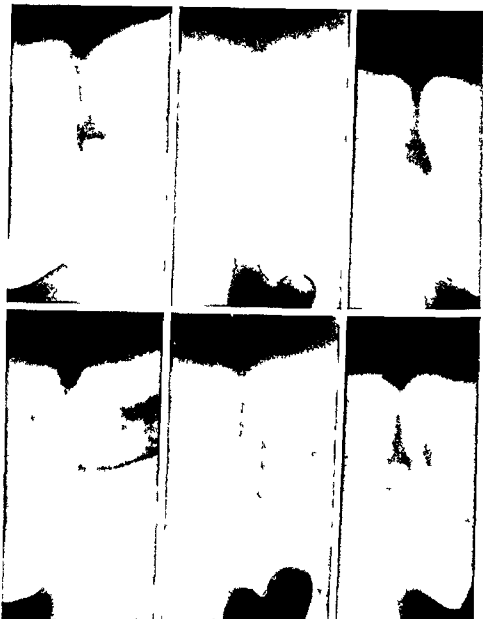


Fig 9 Enlargement of the right Cowper s gland displaces the diaphragmatic urethra in a curve convex to the left this is suggested in the injection film (upper row) but distinctly shown in the contraction film (lower row) Cf fig 4 p 458 of earlier paper (25) The prostatic urethra shows characteristic so called congenital prostatic atrophy the seminal colliculus being large and of apical location with the supra collicular sinus widened owing to a large prostatic utricle

upon the contrast medium in the diaphragmatic urethra resulting from contraction of the external sphincter (Fig 6)

The downward movement of the prostate and urogenital diaphragm on straining and even *more on micturition* is somewhat arrested and modified by the ligamentous fixation of the external sphincter and the prostatic apex to the dorsal surface of the pubic symphysis As a result the prostate will be tilted backwards also when the pelvic organs are depressed This



Fig. 10. Prostatic carcinoma with invasion of the pelvic walls and perirectal tissues; fixation of the pelvic floor but not the upper portions of the prostatic or bladder. Changes in position of the diaphragmatic urethra are impeded, while other portions are slightly tilted on straining (b) and particularly on micturition (c) as compared with the resting position during injection (a); extra bends develop in a part of the urethra in a portion corresponding to the fixed region.

is best demonstrated roentgenographically during micturition when the tone of the levatores muscles and sphincter is low and the depression is marked, but it is less distinct or imperceptible in the type of straining in which the intra-abdominal pressure is increased and the entire pelvic floor, and hence the external sphincter as well, are contracted (as on coughing or sneezing).

These ligaments in women are inserted on the proximal and central thirds of the urethra and, as in men, are in close contact with the detrusor muscle and the external sphincter. If the levatores ani muscles are for some reason damaged or distended, as following delivery, the pelvic organs will lie low or will be depressed abnormally far on micturition or straining. This will stretch the external sphincter between its attachment to the pubo-urethral ligament and its course around the depressed diaphragmatic urethra. Nevertheless, although at rest the urethral lumen is usually closed, a sudden rise in intra-abdominal pressure on coughing or sneezing will render the sphincter action inadequate and urine may escape, a condition known as stress incontinence. Jeffcoate (13) and Jeffcoate & Roberts (14) have expressed the view that in stress incontinence the angle normally present between the almost horizontal bladder floor dorsal to the internal urethral orifice (the trigonal area) and the upper portion of the posterior urethra is almost straightened out. The bladder in this event will continue directly into the urethra at rest as in micturition. This may be due to incompetence (rupture or distension) of those fibres of the levatores ani muscles that extend to these areas. In women fibres from these muscles are inserted into the antero-lateral and proximal portions of the vagina close to the periurethral tissues and dorsal to the internal urethral orifice.

In normal circumstances, when the usual angle between the bladder floor and urethra is present, the tone of the smooth muscles around the innermost part of the urethra is sufficient to prevent the escape of urine from the bladder to the posterior urethra at rest. A sudden rise



Fig 11 Prostatic carcinoma with fixation to the pelvic walls a) Injection film b) contraction film no elevation occurs despite satisfactory contraction of the pelvic floor c) Injection film e) contraction film after one month's intensive radiation therapy motility is restored indicating that the fixation to the pelvic walls has disappeared

in intra abdominal pressure will result in a reflex contraction of the pelvic floor musculature including the external sphincter increasing the resistance of the posterior urethra and preventing leakage of urine These mechanisms are impaired in stress incontinence and protection against the passage of urine on sudden and unexpected rises in intra abdominal pressure is inadequate But a slower and even considerable rise in pressure that is foreseen may be countered by a voluntary increase in the tone of the striated muscles and incontinence prevented (JEFFCOATE & ROBERTS and others)

Disorders of this type are amenable to surgical correction by restoring the normal relation of the external sphincter to the diaphragmatic urethra and repairing its overdistension Section of the pubo urethral ligaments as performed by MULVANY (30) and INGELMAN SUNDBERG (10) interrupts the fixation of the sphincter to the symphysis permitting its anterior part to fall to the level of its posterior segment in the urogenital diaphragm and thus improving its contraction The improvement is however frequently only temporary owing to subsequent cicatricial shrinkage Operations such as reconstruction of the levatores ani muscles (e g ALDRIDGE (1) INGELMAN SUNDBERG (11) on the other hand raise the depressed pelvic organs so that the urogenital diaphragm and external sphincter assume a normal level in relation to the symphysis pubis this corrects the overstretching of the sphincter and restores its function

Elevation of the lower urinary tract in motility studies The cranial displacement of the posterior urethra in the 65 cases exceeded 1 cm in 4 cases, ranged from 2 to 10 mm in 43, and was less than 2 mm in 18 cases These 18 cases included 6 in which, although the contraction of the pelvic floor was regarded as of ordinary strength, no displacement of the posterior urethra was demonstrable, the external sphincter was contracted (that is the diaphragmatic urethra was emptied) in these 6 cases so that there could be little doubt that the contraction was correctly performed

Irrespective of the magnitude of the displacement the motility was classed as normal or 'according to rule in 41 cases, and as abnormal or deviating

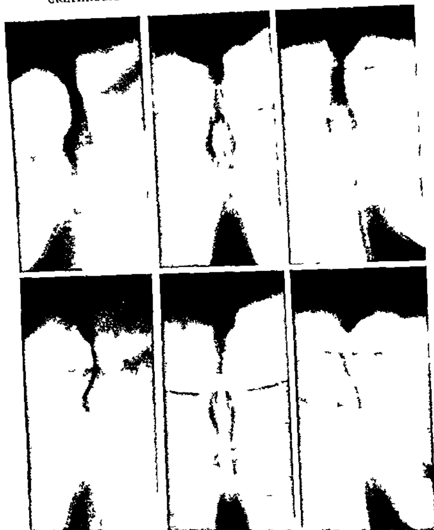


Fig 12 Acute l ft p ostato-ves cul tis displaces the correspond ng segment of the poste rio ur thra *two small calculi in the right prostatic lobe The displacement is shown* more dist nctly n the cont act on film (lower row) than in the inj ct on films (upper ow)

from rule in 18 cases In the 6 cases mentioned above in which no displacement was observed this differentiation was not practicable in 5, while in 1 case the contraction film revealed lateral displacement (not demonstrated on the injection film) the motility was therefore, regarded as abnormal

Fluoroscopy shows that the patient as a rule has difficulty in maintaining maximal contraction of the pelvic floor for more than a short while it may therefore be difficult exactly to synchronize the exposure with the contraction

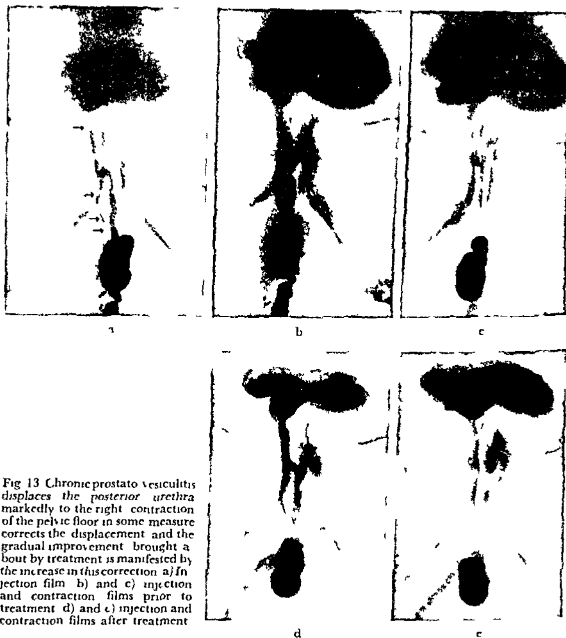


Fig 13 Chronic prostato vesiculitis *displaces the posterior urethra* markedly to the right contraction of the pelvic floor in some measure corrects the displacement and the gradual improvement brought about by treatment is manifested by *the increase in this correction a) In*jection film b) and c) injection and contraction films prior to treatment d) and e) injection and contraction films after treatment

if the patient has not practized under fluoroscopic control before the exposure However, in almost two thirds of instances the degree of evacuation, assessed by the emptying of the diaphragmatic urethra and the magnitude of the displacement, agreed fairly closely The emptying was, however, often more extensive than the elevation Slight displacement cannot therefore be taken to suggest a reduction in motility in cases in which a probable decrease in both the quantity of contrast medium in, and the luminal width of, the diaphragmatic urethra indicate that active emptying has taken place owing to contraction

prior to exposure (Fig 7) It would seem that the contraction of the external sphincter is easier to maintain than that of the levatores ani muscles In the six cases mentioned above, in which the contraction of the pelvic floor was effective and evacuation satisfactory, but in which no upward displacement was observed the explanation may possibly be that the exposure coincided with a late phase of pelvic floor contraction

The underlying cause may lie in a pathologic change when the elevation is distinct but evacuation proportionately poor This is exemplified by the case illustrated in Fig 8 in which diminishing contrast medium corresponding to the muscular sphincter nudae according to MORALES & ROMANUS (25), revealed contraction of the pelvic floor muscles Motility of this type was noted in 10 cases in the present series one case of untreated carcinoma of the prostate (Fig 8) — also with thrombosis incontinence and prolonged indwelling cath eter — one of prostatic carcinoma with metastases treated with hormones 7 of widespread inflammatory lesions of the urethra prostate and seminal vesicles and one case of bladder papilloma treated surgically

Elevation of the gas bubble in the rectum indicated that the subject con tracted the pelvic floor musculature in one case in which the emptying of the diaphragmatic urethra was incomplete and displacement failed to occur The abnormal motility of the urethra may in this instance be attributed to wide spread tuberculous changes of the prostate and seminal vesicles and to strictures

It would appear likely to the present writers that vigorous holding back assessed by the complete emptying of the contrast medium from the diaphrag matic urethra resulting from contraction of the external sphincter is accom panied by contraction of the levatores ani muscles This contraction is initial and virtually almost momentary while the contraction of the sphincter may be maintained for a longer period The absence of upward displacement did not consequently indicate that the motility was abnormal If however, the emptying of the diaphragmatic urethra was also incomplete, the examination was regarded as a failure

Deviating motility or complete fixation of the posterior urethra Disorders of the male genito urinary tract may lead to its fixation to the pelvic walls as by infiltra tion by prostatic carcinoma or as a result of perivesicular or periprostatic inflammation

Active contraction of the pelvic floor may bring about abnormalities in urethral motility so that the prostate is neither elevated nor tilted in the saggital plane according to rule but is straighter or inclined in a frontal plane, with or without some rotation around a vertical axis The latter might be accounted for by eccentric enlargement of the prostate owing to its position between the almost vertical pubo rectal muscles Deviations from the normal of this type may increase the probability of prostatic carcinoma or inflammatory conditions of the prostate and adnexal glands, and prompt closer investigation Evaluation

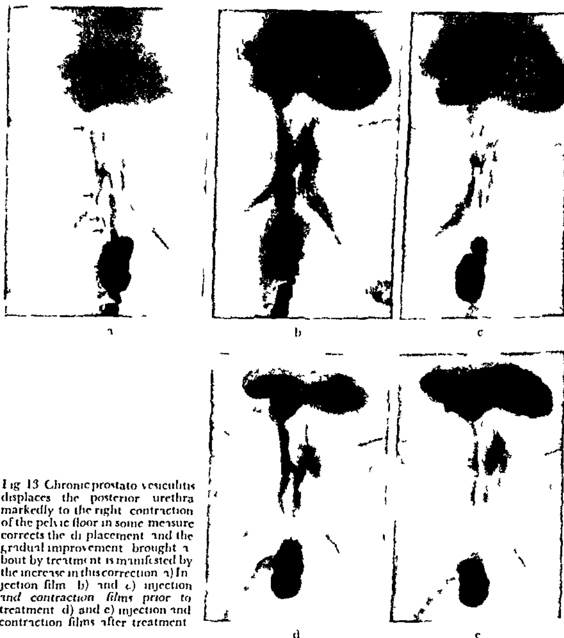


Fig. 13. Chronic prostato-vesiculitis displaces the posterior urethra markedly to the right; contraction of the pelvic floor in some measure corrects the displacement, and the gradual improvement brought about by treatment is manifested by the increase in this correction. a) Injection film, b) and c) injection *and contraction films prior to* treatment, d) and e) injection and contraction films after treatment.

if the patient has not practized under fluoroscopic control before the exposure. However, in almost two thirds of instances the degree of evacuation, assessed by the emptying of the diaphragmatic urethra and the magnitude of the displacement, agreed fairly closely. The emptying was, however, often more extensive than the elevation. Slight displacement cannot therefore be taken to suggest a reduction in motility in cases in which a probable decrease in both the quantity of contrast medium in, and the luminal width of, the diaphragmatic urethra indicate that active emptying has taken place owing to contraction

Case 1 (Fig 10) Male aged 65 This was reported as Case 9 in an earlier paper on shelf tumours (9) This man had suffered from constipation and colicy pain for years no urinary symptoms A barium enema examination disclosed a stricture involving the distal segment of the bowel and in addition there were signs of bone metastases rectal carcinoma was considered probable

Urethrography showed slight anterior displacement of the distal portion of the posterior urethra and marked deviation of its supracollicular part to the left The emptying ability of the posterior urethra was not notably abnormal but the motility of the pelvic floor as seen on contraction straining and micturition was appreciably impaired (No change in the position of the diaphragmatic urethra was ever observed) The appearances were suggestive of prostatic carcinoma owing to displacement of the infracollicular portion of the posterior urethra (coexistent benign hypertrophy of the prostate displaced the supracollicular part) and to the fixation of the pelvic floor as well as the extrarectal tissues Biopsy revealed widespread prostatic carcinoma infiltrating the pelvic floor and constricting the rectum

Case 2 (Fig 11) Male aged 61 with difficulty in micturition for about two months Digital examination revealed enlargement of the prostate which was lumpy hard and fixed to the pelvis bone metastases were present

Urethrography (Fig 11a) revealed elongation and displacement of the entire posterior urethra to the right and forwards suggesting carcinoma of the prostate The seminal colliculus was small and flat the prostatic sulci were slightly irregular particularly near the openings of two contrast filled prostatic ducts containing calculi Contraction of the pelvic floor led to no perceptible change in position although the emptying of the diaphragmatic urethra was good and that of the prostatic urethra usual in amount this suggested malignant invasion of the pelvic walls One month s intensive local radiation therapy led to amelioration of both symptoms and signs Further urethrography a month later (Fig 11b) showed the urethral displacement to have decreased and the prostate to be normally elevated suggesting that the fixation to the pelvic wall was no longer present that is the malignant infiltration had diminished

Case 3 (Fig 12) Male aged 38 with signs for several years of prostato-vesiculitis with recto-perineal pain epididymitis with necrosis and recent stenosis of the left ureter with a stone close to the point at which the ureter traversed the left seminal vesicle On digital examination the prostate was slightly enlarged and inelastic the right seminal vesicle was large uneven and the left was oedematous very tender fixed and ill-defined

Urethrography showed the seminal colliculus to be large and somewhat lobulated on the right side and the prostatic sulcus to be slightly wider and more irregular on the right than on the left side two small calculi lay in the right prostatic lobe By the contraction film (Fig 12b) it was demonstrated that the emptying of the prostatic urethra was unusually complete but that the elevation of the urethra was accompanied by marked displacement of its supracollicular portion in a curve suggesting an expansive process on the left side This was presumed to be a left acute prostato vesiculitis which agreed with the clinical findings

Case 4 (Fig 13) Male aged 6? with difficulty in micturition Squamous-cell carcinoma of the bladder had been electroresected transurethrally five years earlier and radiation therapy given On digital examination the prostate was of normal size firm and not obviously malignant Multiple strictures of the anterior urethra precluded endoscopy The passage of sounds was followed by gradual improvement

Urethrography with motility studies revealed strictures and a large number of contrast filled Morgagni s lacunae in the anterior urethra widening of the left prostatic sulcus and numerous filled cavities in the prostate (Fig 13 a and b are injection films) The reduction of contrast medium in the posterior urethra in the contraction film (Fig 13c) was found to be

is however difficult because of the frequent deformation of the prostatic urethra evident in injection films in the presence of disorders, and also by the alteration in the shape of the urethral lumen resulting from the evacuation of the contrast medium brought about by contraction of the pelvic floor But in occasional instances, as exemplified by the cases described below, abnormal motility of this type may be correlated closely with the clinical findings

The displacement was classed as *normal* in 41 cases Conditions could not be evaluated with confidence in 6 while in 18 cases the displacement was abnormal Sixteen of these latter 18 cases had conditions in which fixation of the posterior urethra was likely 6 cases of carcinoma of the prostate 2 of carcinoma of the bladder treated surgically and with radiation 7 of chronic prostato vesiculitis (including 2 cases with large cavities and inflammatory infiltrates and one with tuberculous prostatitis) and one case of peritoneal carcinosis with metastases in and around the pouch of Douglas Urethral stricture coexisted with infiltration after right sided vesiculitis in one of the two remaining cases and in the other the prostatic apex was merely elevated on voluntary contraction of the pelvic floor without its apical portion simultaneously being drawn ventrally This was the only instance in which any correspondence between the roentgen findings and the vague genito urinary signs and symptoms could not be found

For the correct appraisal of the correspondence between the roentgenographic and clinical findings in these cases of deviating motility it should be noted that fully normal motility was present in several cases with the same diagnoses and similar symptoms including cases of prostatic carcinoma and chronic prostato vesiculitis with cavities

It will be realized that the motility examination described in the present paper may only in exceptional cases afford information of cardinal importance for the diagnosis It may, however, as exemplified by the cases described below, reveal details helpful in the choice of treatment or in the evaluation of therapeutic results

Repeat examinations are capable of demonstrating a decrease in fixation, or abnormal displacement on regression of inflammatory lesions, and diminishing cicatricial shrinkage or malignant infiltration Changes of this type were in the present study frequently seen earliest and best in the contraction films, and not until later in those exposed during injection If abnormal or deviating displacement is demonstrable in the injection film but is not perceptible or is less distinct in the contraction film, this may be taken to suggest variability indicative of a benign lesion or of amelioration after treatment

The contraction film in some instances revealed displacement or deformation of the diaphragmatic urethra of the type associated with cowperitis (MORALES & ROMANUS) (25), although the injection film was practically normal (Fig 9) The displacement in these cases may have been masked by urethral dilatation during the injection but emerged on the contraction film when the urethral lumen was less distended Another possible explanation may have been that it is only on muscular contraction that the altered gland is brought into so close a relationship with the urethra as to affect its lumen

The following cases exemplify the value in certain circumstances of motility studies of this type

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of the usual magnitude in relation to the injection film and the displacement to the right was seen to be slightly reduced as the organs were elevated. After some 6 months treatment which led to *striking improvement in symptoms and signs* urethrography indicated in the injection film (Fig. 13d) that the conditions were largely unchanged, while in the contraction film (Fig. 13e) the lateral displacement was almost fully corrected.

This case exemplifies the close correspondence between the subjective and objective improvement of severe prostato-vesiculitis with strictures.

SUMMARY

A series of 65 cases in which urethral motility on voluntary contraction of the pelvic floor was studied with a highly viscous water soluble contrast medium is reported. The normal motility of this tract may be altered by fixation of the prostate to surrounding structures by inflammatory or malignant infiltration. The examination may sometimes be helpful in the choice of treatment and the assessment of results.

ZUSAMMENFASSUNG

In 65 Fällen wurde die Harnröhre mit einem viskosen wasserlöslichen Kontrastmittel gefüllt. Die Verschieblichkeit der hinteren Harnröhre beim volontären Beckenbodenkontraktion wird durch entzündliche oder neoplastische Infiltration der umgebenden Gewebe beeinträchtigt. Diese Tatsache kann diagnostisch bedeutsam sein und kann dazu dienen die Therapie zu beeinflussen oder zu kontrollieren.

RÉSUMÉ

Les auteurs ont étudié sur 65 sujets, grâce à un moyen de contraste hydrosoluble très visqueux, la motilité de l'urètre au cours de la contraction volontaire du plancher pelvien. La motilité normale de ce conduit peut être modifiée quand la prostate est fixée aux organes voisins par une infiltration inflammatoire ou maligne. Cet examen peut dans certains cas être utile pour choisir le traitement et pour juger ses résultats.

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Fig 1 Deformity of femoral vein in inguinal endometriosis a) at th end of menstruation b) between menstruations c) at the time of missed menstruation d) at the end of subsequent men truation

The similarity between the normal endometrium and the abnormal tissue present in endometriosis is not only histologic both respond in essentially the same way to the various cyclic hormonal stimuli The resultant changes include cyclic swelling of the tissue which is apparently responsible for some of the signs and symptoms occurring in endometriosis in general Inguinal endometriosis is sometimes recognized preoperatively by the periodic occurrence or accentuation of pain or tenderness in the groin or by the periodic variation in size of an inguinal tumour or swelling Any deformity of the femoral vessels caused by the condition might be expected to undergo a similar variation in size with the phase of the menstrual cycle The presence of such a periodic variation might in turn be taken as highly suggestive of inguinal endometriosis

No angiographic observations in inguinal endometriosis seem to be on record and periodic deformation of the femoral vessels is apparently unknown We have observed a case in which this sign was angiographically demonstrated and helped to establish the diagnosis preoperatively

The patient aged 43 sought advice for varicose veins and periodic swelling of the left leg The varicosities were found to be slight and apparently in sufficient to explain the oedema which was described as sometimes being marked and extensive though more often moderate in degree and then confined to the ankle A transverse scar was observed in the suprapubic region on inquiry this

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ANGIOGRAPHY IN THE DIAGNOSIS OF INGUINAL ENDOMETRIOSIS

by

Georg Theander and Knut Haeger

Inguinal endometriosis, which was classically described by Cullen in 1896, has received considerable attention in the literature (e g Judd & Foulds 1923, Sampson 1925, 1926, Polster 1926, Adams Ray 1933, Harbitz 1934, Masson 1945, Moloney 1949, Dormandy 1956) The main change in this unusual condition consists in the growth of tissue resembling endometrium in or close to the inguinal canal, the site of predilection being the attachment of the round ligament or, if a femoral or inguinal hernia co exists, the serosal sac of the hernia Local fibrosis is inherent in the condition, and the abundant fibrous tissue tends to undergo firm contraction with resultant rigidity and puckering The inguinal endometriosis may infiltrate the upper part of the thigh and it is sometimes felt on palpation as a discrete lump in the groin It would seem reasonable to assume that such changes tend to deform or displace the femoral vessels at this level A case is in fact on record in which operation revealed that inguinal endometriosis had caused local compression of the femoral vein (Laroyenne et coll 1930) The incidence of such venous deformities cannot be deduced from the literature, since most of the available reports on inguinal endometriosis do not mention the vascular anatomy

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endometriosis was evident in the pelvis In and below the inguinal canal the femoral vessels were surrounded by a thick and remarkably firm sheath of fibrous tissue compressing the vein and though less markedly the artery The abnormal fibrous tissue extended below the junction of the femoral and the saphenous veins the latter vessel being displaced cranially and kinked con tracted tissue also surrounded the obturator vein The left ovary and the uterus, including the entire left round ligament were extirpated, and after transsection of the inguinal ligament nearly all the abnormal perivascular tissue was removed The femoral vein was afterwards seen to widen The saphenous vein was ligated and stripped below the ligature

Histologic examination of the specimens revealed a small uterine adenomyoma and intramural endometriosis of the uterus and left fallopian tube but no endometriosis was evident in the left ovary The round ligaments were normal The fibrous tissue removed from the left groin and thigh was found to contain a number of cell islands some of which were glandular in structure and made up of regular cylindric epithelium The histologic ap pearances of these lesions indicated endometriosis (Bergman)

The swelling of the leg disappeared and the crural ulcer healed within a few days of the operation Angiography performed four months later *revealed* a persistent deformity of the femoral vein but the lateral displacement was less marked and the outline of the vessel somewhat different A collateral venous circle had developed via the widened obturator vein The course of the femoral artery had become normal

Discussion

Inguinal endometriosis is rarely recognized preoperatively, most of the cases on record being diagnosed at biopsy Of 20 cases surveyed by JIMENEZ & MILES (1960) *for example* a correct preoperative diagnosis was made only in 7 This series included 4 personal cases, 3 of which were mistaken for incarcerated hernia but the condition is most often preoperatively classed as an unspecified lump in the groin It is tempting to assume that angiography could afford more accurate diagnosis in such cases since this examination as illustrated in the present case might reveal a characteristic periodic deformity of the femoral vessels

SUMMARY

A case of inguinal endometriosis in which angiography revealed displacement of the femoral vessels and local narrowing of the femoral vein varying with the menstrual cycle is reported

ZUSAMMENFASSUNG

Ein Fall von Inguinalendometriose wird berichtet in dem eine Lateralverschiebung der Femoralgefässe und eine mit dem Menstruationszyklus variierende Verengung der Femoral vene angiographisch nachgewiesen wurden



Fig 2 Femoral artery slight lateral displacement

was said to date from five years back and to be due to the surgical treatment for some genital tumour

The patient underwent angiography of the left leg including ascending phlebography, retrograde femoral phlebography and femoral arteriography It became apparent from these examinations that parts of the soft tissues in the left groin and upper anterior portion of the left thigh were abnormal in consistence This could not be demonstrated with certainty on direct palpation but was quite obvious on puncture, since, on approaching the vessels, the needle was felt to pierce a deeply situated and fairly thick layer of firm tissue resembling a contracted scar The angiograms obtained confirmed the diagnosis of slight venous insufficiency, with small varicosities in the superficial veins No 'strain obstruction syndrome' (GULLMO 1956, 1957) could be demonstrated but somewhat below the inguinal ligament the femoral vein was displaced laterally and considerably narrowed, mainly by a distinct rounded indentation, about 5 cm in length, in its medial wall (Fig 1a) The deformity was constant, being demonstrated on repeated injections of contrast medium, and not affected by straining The femoral artery was displaced slightly laterally at the same level (Fig 2)

The information so far obtained was considered suggestive of inguinal endometriosis, and further inquiry into the history of the patient gave support to this diagnosis It could be established that the operation performed five years previously, which was actually for incomplete abortion, had revealed the presence of bilateral ovarian endometriosis Resection of the left ovary and right sided salpingo oophorectomy had been carried out Swelling of the left leg had been first observed about a year after the operation it occurred at the end of the menstruations and lasted for three or four days Since then it had gradually increased in duration and severity and persisted to some degree throughout the cycle

Surgical treatment was offered but temporarily refused On further observation of the patient, the close relationship of the swelling to the menstrual periods was confirmed, and a corresponding cyclic variation in the roentgenographic appearance of the femoral vein was demonstrated The narrowing of the vessel was thus less marked and the indentation somewhat shorter between the periods than at the end of the menstruations Moreover, during amenorrhoea which developed while the patient was under observation and persisted for three months, the monthly increase of the swelling as well as the exaggeration of the vascular deformity failed to occur (Fig 1) The swelling reappeared on return of the menstruations, and a crural ulcer subsequently developed

At operation a 'chocolate cyst was found in the left ovary, but no extragenital

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QUANTITATIVE ASSESSMENT OF MITRAL AND AORTIC INSUFFICIENCY BY ANGIOCARDIOGRAPHY

by

H ARVIDSSON and J KARNELL

It is possible to detect the presence of regurgitation in most cases of mitral and aortic valve lesions by physical examination and probably few cases of significant insufficiency would go unrecognized if the clinical study was restricted to physical examination ECG phonocardiography and right heart catheterization including pressure measurements This approach to the diagnosis however gives only a qualitative indication of the insufficiency Several attempts have been made during the last decade to quantify the insufficiency in mitral and aortic valvular disease The problem has practical importance in the indications for surgery and is also of theoretical interest the altered haemodynamics may be studied by repeat examinations The possibility that mitral insufficiency may have a tendency to increase in time and that the degree of insufficiency may decrease during the progression of the valve lesion may also be investigated by a quantitative method

Few quantitative methods are available at present The indicator dilution technique is the one most commonly used (WOODWARD et coll SINCLAIR et coll MILNOR KORNER & SHILLINGFORD LEVINSON et coll) and many different applications of this technique have been tried The most important contribution is probably the one by KORNER & SHILLINGFORD These authors used

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RÉSUMÉ

Les auteurs présentent un cas d'endométriose inguinale où l'angiographie a montré un déplacement des vaisseaux fémoraux et un rétrécissement local de la veine fémorale, variant au cours du cycle menstruel

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Methods and Material

The method of volume determination of the left ventricle was detailed earlier (ARVIDSSON 1958 1961) It was demonstrated that there was a reasonably good correlation between angiocardiographic output determination of the left ventricle and the Fick minute volume determination in cases without mitral or aortic insufficiency The study formed the basis of the present analysis and the method of volume calculation was the same in the two investigations For method description the reader is referred to a previous paper (ARVIDSSON 1961)

The angiocardiographic methods and equipments were the same as in the previous study The Fick output determination was also performed in a similar way

The clinical material consisted of cases of mitral and/or aortic insufficiency The lesions were not isolated in several cases mitral and/or aortic stenosis were also present (see Table I) The cases were selected from a much larger clinical material The following prerequisites should be fullfilled in an examination for the cases to be included

1 Satisfactory minute volume determination by the direct Fick method performed immediately prior to angiocardiography

2 Regular heart beat during the angiocardiographic examination — examinations with one or two ventricular extra systoles during the first part of the contrast injection were accepted if a sufficient number of films during the phase of regular heart beat were obtained,

3 Satisfactory ECG and exposure recordings during angiocardiography so that the position of the exposure in the heart cycle could be ascertained

4 Exposures occurring at maximum systole (at the end of T wave) and at maximum diastole (at the QRS complex) must be available for measurements

The material selected according to these principles consisted of 20 cases Ten cases were examined by pulmonary artery contrast injection four by left ventricular contrast injection and five by left ventricular and aortic injections in order to evaluate the mitral as well as the aortic insufficiency In one case injections were performed in the pulmonary artery and the aorta

The qualitative diagnosis offered no problems in most of the cases When left ventricular and aortic injections were performed the insufficiency could be observed directly at angiocardiography Stenosis of the mitral or aortic valve could also be studied directly in the films The anatomic observations were substantiated by the pressure measurements Three of the examinations with only pulmonary artery contrast injections followed mitral commissurotomy and the mitral insufficiency was noted by the surgeon at the end of the operation In the remaining cases of pulmonary artery contrast injection the diagnosis was based on the combined angiocardiographic catheterization and clinical findings

right side injection of an indicator with peripheral arterial sampling. By analysis of the concentration curves obtained, they claimed to be able to determine the degree of insufficiency. LEVINSON et coll. tried to improve the method of KORNER & SHILLINGFORD by injecting the indicator into the left ventricle with simultaneous sampling from the left atrium and a systemic artery. They found the method unreliable due to incomplete mixing in the left ventricle of the blood and indicator, and the sampling from the left atrium was not dependable. They stated "However, information obtained from the atrium, especially if that chamber is enlarged, is subject to profound sampling error. It is in this respect that angiocardiography, although only semi quantitative, may have an advantage over indicator dilution". Another disadvantage with the indicator dilution technique is that it gives no information about the anatomy of the heart chambers and valves. It cannot therefore replace angiocardiography in the analysis of mitral and aortic valve lesions.

A promising method of haemodynamic analysis was developed by PORJE & RUDEWALD. They analyzed the acceleration of the blood in the ascending aorta with a double lumen catheter and a specially designed differential manometer. With the aid of the differential pressure curves obtained and the cross sectional area of the aorta determined by aortography, they were able to analyze the momentary forward and backward flow in the aorta. The method was hitherto only used occasionally in aortic insufficiency but it will probably prove very valuable in the study of aortic valve lesions; it is unsuitable in mitral valve disease.

A new approach to the assessment of the end diastolic and end systolic volumes of the left ventricle was recently published by FOLSE & BRAUNWALD. They used a 'precordial dilution technique' which involved injection of radioactive material into the left ventricle. A detector was placed over the left ventricle and the decrease in activity stroke by stroke was used as a measure of the fraction of blood in the left ventricle that was ejected per beat. The output was determined by the ordinary dilution technique and it was possible from the results to determine both the end diastolic and end systolic volumes of the left ventricle with considerable reproducibility.

Angiocardiographic determination of the left ventricular stroke volume combined with a cardiac output determination e. g. by the direct Fick method is a new method for the quantitative determination of the regurgitation in mitral and aortic insufficiency. This method of examination has the advantage that the anatomy as well as the haemodynamics may be analyzed by the same procedure. This approach was used earlier by GRIBBE et coll. in the dog as well as by BRUCE & CHAPMAN in human subjects, and volume determinations were carried out by BUNNELL et coll. in a paediatric material of coarctation of the aorta. No methodical study of the degree of insufficiency was made, however. An account is now given of the method with application to a relatively small clinical material.

Table 1 *(cont)*

Heart rate	LV minute volume angiocardiographic L	Minute volume Fick determ	Heart rate during Fick determ	LV efficiency Fick/angio 100	Left ventricular volume curve	Pressures PA	PA Mean	PCV Mean	LV	Ao
73	12 3	3 9	60	30	+	50/23	34	20		
100	1?	5 5	68	45	+	82/4?	60	2?		
72	13	5 3	60	40	+	71/29	47	2? 4		
9?	8 5	4 8	60	55	—	4?/11	23 5	15 ?		
10?	8	4 9	70	60	—	33/7 5	21	9 5		
10	8	3 3	7?	40	—	49/18 4	30	10		
10?	11 0	5 1	76	4?	—	73/33	48	33	113/0–? 5	116/77
18?	8 5	4 6	60	55	+	28/14	18	10	145/0–16	125/67
60	18	2 1	57	10	—	33 5/15	21	17	120/3 5 14	123/91
100	11	4 7	58	45	—		10 8	10 3		
100	26	6 6	74	25	+	30/9	17	10	128/6 5–10	123/64
70	13 3	6 6	77	50	+	16 2/7 5	12	7 5		
100	24 5	3 8	60	15	+	24/11	20	15	98/5–13 5	9?/56
48	9 6	7 1	54	7?	+	23/8	1? 5	11 5	1?6 5/0 9	123/71 5
100	7 5	4 4	—	60	+	18 6/9	14	7 5		
110	7 7	3 9	50	50	+	20/4	10 5	5 7	133/0	13?/68
135	16	4 7	7?	30	—	20/14	18	15		
7?	7 1	4 7	60	6?	+	3?/15	21	16 5	121/5–14 5	126/60
110	6	3 8	60	65	+	37 5/15	2?	17 5	126/1 5 11	111/56
120	12	4 0	50	30	+	43 5/16 5	23 5	19 5	230/0–12	194/70

age) from 100 A plus sign in the next column in the table denotes that it was possible to construct a volume curve for the left ventricle i e a sufficient number of exposures with adequate filling of the left ventricle was distributed evenly over the heart cycle The pressure data from the cardiac catheterizations are given in the last columns They will not be discussed here but give an idea of the severity of the valve disease especially the degree of mitral and aortic stenosis

The purpose of the present study was to demonstrate mainly the applicability of the method in insufficiency cases the clinical observations as correlated to the degree of insufficiency will therefore not be discussed A publication on the clinical aspects of the material is planned

Results

A *The degree of insufficiency* The degree of insufficiency was recorded as a percentage quantity in all cases as is demonstrated in Table 1 The amount of

Table 1

Case No	Age	Sex	Diagnosis	Heart volume total ml	Heart volume ml/m² BSA	Site of injection	LV end diastolic volume ml EDV	LV end systolic volume ml ESV	LV stroke volume ml
1	43	M	MSI postop	990	540	PA	200	30	170
2	44	F	MSI	1 240	740	PA	160	40	120
3	43	F	MSI postop	1 050	620	LA	220	40	180
4	42	F	MSI	850	440	LA	190	100	90
5	39	F	MSI + tricusp incompetence	1 240	760	PA	135	60	75
6	35	F	MSI postop + AoS	770	460	PA	105	30	75
7	37	M	MSI	1 400	710	LA	135	30	105
8	38	F	MSI	730	410	LV	130	30	100
9	21	F	MI	1 250	820	LA	370	70	300
10	30	M	MI	1 100	550	PA	180	70	110
11	25	F	MI	1 480	950	LA	360	100	260
12	24	F	AoI	590	370	PA	240	50	190
13	38	M	MI + AoI	1 420	780	LA + Ao	330	85	245
14	27	M	MS + AoI	1 010	570	LA + Ao	240	40	200
15	43	F	AoSI	630	380	PA	120	45	75
16	33	F	MS + Ao(S)I	870	550	LA	95	25	70
17	33	F	MS + AoI	760	490	PA + Ao	195	75	120
18	48	F	MS + AoI	910	600	LA + Ao	110	15	95
19	34	F	MS + Ao(S)I	620	400	LA + Ao	80	25	55
20	56	M	MS + AoSI	1 390	700	LA + Ao	145	45	100

Table 1 is a survey of the case material The total and relative heart volumes are included in order to give information about the cardiac enlargement which is a good indicator of the severity of the heart lesion The absolute volume of the heart was calculated by the method of JONSELL and the relative volume by the body surface area in square meters The maximum (EDV) and minimum (ESV) volumes of the left ventricle are given in milliliters as well as the difference between them i e the left ventricular stroke volume The angiocardiographic minute volume of the left ventricle, obtained by multiplying the stroke volume and the heart rate, is compared with the Fick minute volume The efficiency of the left ventricle was calculated according to the following principles the output determined by the Fick method was divided by the left ventricular minute volume determined angiocardiographically The quotient was multiplied by 100 to express the efficiency in percentage terms If the percentile insufficiency is preferred, this figure can be obtained by subtracting the efficiency (as a percent

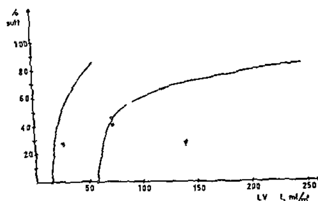


Fig 2 End systolic (black dots) and end-diastolic (circles) volumes of the left ventricle related to the degree of insufficiency as a percentage The symbols at the x axis (the base of the regression curves) are the average systolic and diastolic volumes of the left ventricle in the earlier material of cases without insufficiency There is a marked increase in end-diastolic volumes at about 50 per cent insufficiency (I) denotes Case 14 which had marked bradycardia during angiocardiography

mum systolic pressure is reached within the left ventricle and the blood regurgitates to the left atrium where the pressure is significantly elevated from zero The pressure drop of the pendulum blood will consequently be higher in aortic than in mitral insufficiency

B *Left ventricular maximum (EDV) and minimum (ESV) volumes* The left ventricular maximum and minimum volumes were increased in the present material as compared with the previously presented material of cases without insufficiency The relative volumes per m² body surface area were calculated in order to compensate for differences in body size The means within the two groups and the standard deviations are given in Table 2 The dispersion of the values was considerable in all groups but significantly higher in the material of insufficiency This is natural because cases with different degrees of insufficiency were mixed

A linear relationship between EDV and ESV appeared to exist within the two materials The correlation between the two parameters is demonstrated graphically in Fig 1 The present material is given with the individual observations and the calculated regression equation which is

$$ESV = 0.42\,EDV - 26 \quad \text{(full line Fig 1)}$$

The cases without insufficiency are not given individually but the regression equation is

$$ESV = 0.2\,EDV + 6.7 \quad \text{(broken line Fig 1)}$$

There was a reasonable good linear correlation between EDV and ESV ($r = 0.73$) within the insufficiency material but in the group without insufficiency the correlation was less satisfactory ($r = 0.45$) The low degree of correlation within the latter group may be due to the fact that the end systolic volumes were smaller and consequently the error of measurement was of greater significance It appears from the regression coefficients and Fig 1 as if the quotient

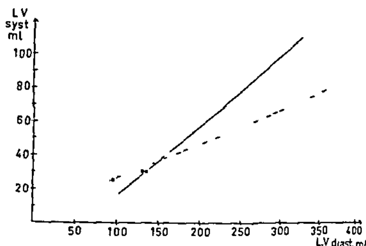


Fig. 1. Relation between end diastolic and end systolic volumes of the left ventricle. The dots represent the individual observations and the solid line the regression line for the present material. The broken line is the regression line for material of cases without insufficiency earlier presented. (The individual observations are not plotted.)

regurgitating blood varied from 25 to 90 per cent to the left ventricular minute volume. Twenty five per cent regurgitation seems to be a reasonable degree of insufficiency but 90 per cent appears to be beyond the capacity of the left ventricle, with an almost ten fold volume output of the left ventricle. This very high degree of regurgitation is evidently compatible with life, even though these cases were in a rather severe clinical condition. The higher degree of insufficiency, in which more than 75 per cent of the left ventricular stroke volume regurgitated was never encountered among the cases with only aortic insufficiency. The small material does not allow a definite conclusion upon this matter but it seems probable that an extreme degree of insufficiency is possible only in connection with mitral incompetence. The energy loss in aortic insufficiency is higher than in mitral insufficiency with the same amount of regurgitating blood, in aortic insufficiency the pendulum blood must be pumped into the aorta with a pressure that is usually above the normal systolic pressure only to return to the left ventricle, where the pressure is practically zero. In mitral insufficiency a significant amount of blood regurgitates before the maxi

Table 2

Comparison between relative volumes of the left ventricle in cases without and with mitral and/or aortic insufficiency

	End diastolic volume ml/m² BSA	End systolic volume ml/m² BSA	Average output (%) of the left ventricle divided by end-diastolic volume	
			Total	Forward
No insufficiency 16 cases (Arvidsson 1961)	57.2 ± 18.2	14.7 ± 7.3	74	74
Insufficiency 20 cases (present material)	110.4 ± 55.1	29.5 ± 15.1	73 °	40

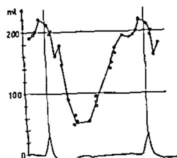


Fig 4 Left ventricular volume curve in Case 3 Calculated volumes of left ventricle plotted against ECG tracing Preoperative study had shown mitral stenosis and slight insufficiency Commissurotomy at the end of operation stenosis partly relieved and insufficiency noticeably increased Angiocardiography performed with injection into pulmonary artery minute volume 13 l minute volume by Fick 5 3 L corresponding to an insufficiency of 60 per cent The volume curve shows relatively little increase in end systolic volume but the end-diastolic volume is increased There is an indentation in the P wave

The total output is the forward output plus the regurgitating volume The percentage of total output was approximately the same in the two materials and the percentage of forward output was naturally decreased in the insufficiency material

C *The cardiac output* The cardiac output in the present material as determined by the direct Fick method generally showed reduced values as compared with the previous material without insufficiency The cardiac index (CI) was determined by dividing the output in litres by the body surface area in m² The average cardiac index in the present material was $CI_m = 2\ 88 \pm 0\ 18$ L and the corresponding value in the previous material without insufficiency was $CI_m = 4\ 21 \pm 0\ 25$ L The difference between the two materials was significant at the 0 1 per cent level In order to evaluate how the efficiency of the left ventricle affected the cardiac index the values were plotted as shown in Fig 3 The degree of linear correlation was relatively low ($r = 0\ 46$) but the cardiac index obviously decreased with increasing insufficiency The regression line was extended to 100 per cent efficiency (Fig 3) and the corresponding cardiac index was found to be approximately 4 litres This tallies well with the average value obtained in the material without insufficiency

D *Left ventricular volume curves* It was possible in 13 of the 20 cases to construct a volume curve for the left ventricle by plotting volume determinations from different heart cycles of the angiocardiography together This was performed as described earlier (ARVIDSSON 1958 1961) Figs 4 5 and 6 give three typical volume curves These have the same shape as the ones obtained in cases without insufficiency (ARVIDSSON 1961) and no characteristic features of the insufficiency curve can be observed The stroke volume is however augmented by an increase both in end systolic and end diastolic volumes, i e the curve is located at a higher level and is of increased amplitude The curve frequently had a plateau at the end of ventricular systole best shown in Fig 6

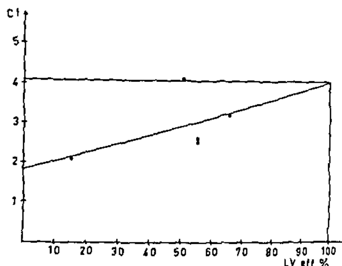


Fig 3 Correlation between left ventricular efficiency as a percentage and the cardiac index (C I) in mitral and/or aortic insufficiency The oblique line is the linear regression equation C I 0 022 LV eff + 1 83 The correlation is relatively low r 0 46 The intersection between the regression line and the 100 per cent efficiency vertical line is marked and at this point the cardiac index is approximately 4 1

LDV/LSV is lower in the insufficiency group than in the group without insufficiency, i e the end systolic volume is relatively increased in insufficiency The small number of cases, however, makes the observations somewhat uncertain The relationships between the relative LDV and LSV in ml/m² BSA and the degree of insufficiency as a percentage is shown in Fig 2 The regression lines were not calculated mathematically but drawn approximately to show the tendency of the relationship The base points of the curves were obtained from the mean values in the previous material of cases without insufficiency, i e cases in which the insufficiency is zero It will be observed from Fig 2 that there is little increase in the relative systolic and diastolic volumes when the insufficiency is less than 50 per cent The regurgitation consequently appears not to be fully compensated for by an increased stroke volume of the left ventricle This means the output is decreased in cases of insufficiency, even of a moderate degree This fact is also confirmed by the comparison of the cardiac output of the two materials, see under heading (C)

In the above analysis the heart rhythm involves a certain error The stroke volume of the left ventricle must increase to maintain the cardiac output if, for instance bradycardia is present In the two materials compared here the average heart rate was approximately the same, in the insufficiency material the average heart rhythm was 100/min and in the material without insufficiency it was 109/min The effect of bradycardia is demonstrated by the case with the special symbol in Fig 2 The relationship between the left ventricular output and the end diastolic volume has a great theoretical interest for the understanding of the performance of the left ventricle under normal and pathologic conditions This was analyzed in the present material as well as in the previously published material of cases without insufficiency The forward and total output of the left ventricle are given as percentages of the end diastolic volume in Table 2

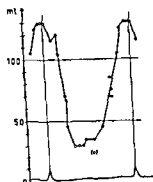


Fig 6 Left ventricular volume curve in Case 8 Mitral stenosis and insufficiency examined by left ventricular injection Angiocardiographic minute volume 8 5 L, and Fick determination 4 6 L, corresponding to an insufficiency of 45 per cent The end-systolic volume is within normal limits and the end-diastolic volume only slightly increased

IV *Area product method* This is a planimetric approach that was used earlier by CHAPMAN et coll It has the advantage of not requiring a regular ellipsoid shape of the left ventricle

V *Simpson s parabolic formula* which was also used earlier by CHAPMAN et coll This method is too time consuming to be used as a routine

DODGE et coll found that all methods tested involved a systematic error the calculated volumes were larger than the known ones All methods showed however a good linear correlation between known and calculated volumes The over estimation of the volumes was thought to be due to an error in the determination of the longest axis in the first three methods method III involved the greatest systematic error DODGE et coll made however the measurement differently from the method used in the present work they used a higher end point of the ellipsoid and discussed only briefly the importance of the trabeculae carnae and the papillary muscles Of the five methods analyzed by DODGE et coll there were only two that were simple enough to be used in routine work viz methods II and III In their study method II showed a good correlation and a small systematic error In order to determine whether method II was superior to the method used earlier by one of us (modified method III) the material of cases without insufficiency (ARVIDSSON 1961) was recalculated according to method II The analysis showed that method II gave less good correlation with the minute volumes obtained by the Fick method than the modified method III This appeared to be a good reason to continue with the same method in the present material as in the earlier study A slight over estimation of the left ventricular volume is made with this method but as discussed earlier this is true for the systolic as well as for the diastolic volume and makes the error in calculation of the stroke volume smaller than the measurement of the individual volumes

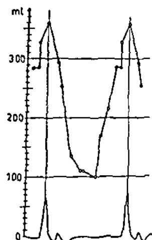


Fig 5 Left ventricular volume curve in Case 11 Predominant mitral insufficiency studied by left ventricular injection Angiocardiographic minute volume of left ventricle 26 L and Fick determination 4 7 L corresponding to 75 per cent insufficiency Considerable increase both in end systolic and end diastolic volumes but general shape of the curve is not different from the one seen in normal cases

Discussion

A *Method of measurement*

A very important paper on the theoretical problems of angiocardiographic determination of the left ventricular volume was published by DODGE et coll These authors analyzed five different methods of assessing the volume of the left ventricle by bi plane angiocardiography The volume of the left ventricle was determined in an autopsy material by injecting the ventricle with varying, known amounts of barium sulfate paste The known volumes were correlated to the volumes calculated by the following methods

I *Spatial method* This is an elaborate but theoretically very attractive approach The method was based on the assumption that the left ventricle had the shape of an ellipsoid One of the advantages of the method was that it compensated completely for the geometric magnification This is a complicated problem since the distortion changes continuously along the long axis of the ventricular ellipsoid which is located in a plane different from both the a p and the lateral projections Unfortunately the method is very time consuming and thus impossible to use in the daily routine For details about the method the reader is referred to the excellent original article

II *Longest measured length method* This is also based on the assumption that the left ventricle has the shape of an ellipsoid The two short axes of the ellipsoid were measured according to the same principles as in the present study, but the long axis was taken directly from the a p or lateral projection whichever had the longest projection of the apico basal ventricular axis (see Fig 7)

III *Three measured lengths method* This is a modification of the method used in the present study, also based on the assumption that the ventricle had the shape of an ellipsoid (see Fig 7)

to make the complete volume analysis For instance, the amount of residual blood in the left ventricle and the rapidity of evacuation of the left ventricle may be analyzed in detail When simultaneous pressure and volume curves for the left ventricle are obtained a volume pressure diagram may also be constructed which indicates the efficiency of the myocardium (ARVIDSSON 1961) This latter observation might be of value in establishing the indications for operation, since the condition of the left ventricular myocardium appears to be of vital importance in the mortality and end results of surgery

C *Comparison with left ventricular volumes obtained by other authors*

The relationship between end diastolic and end systolic volumes was studied by several authors and it is interesting to compare earlier results with those obtained from the present material

FOLSE & BRAUNWALD studied the left ventricular maximum volume by the earlier mentioned isotope technique and reported a volume of 89 $\pm$ 26 ml/m² BSA in a material without insufficiency The present material showed a lower value of 57 2 $\pm$ 18 2 ml/m² BSA FOLSE & BRAUNWALD in their insufficiency material recorded 209 $\pm$ 75 ml/m² BSA but our value of 110 4 $\pm$ 55 1 ml/m² BSA was considerably lower The different results in the insufficiency group might be explained by a difference in the degree of insufficiency even though it does not seem likely that these workers were dealing with twice the degree of insufficiency as compared to ourselves Another possible explanation of the difference is that the heart rate may have been different a factor that was not discussed by FOLSE & BRAUNWALD the heart rate was usually increased during angiocardiography and this naturally decreased the stroke volume if the output was constant However not even this factor is enough to explain the difference and since our volumes are rather too great than too small it is likely that the method of FOLSE & BRAUNWALD gives volume values that are too large

FOLSE & BRAUNWALD reported a 37 $\pm$ 8 per cent end diastolic / forward stroke volume quotient in cases without insufficiency and 16 $\pm$ 5 per cent in cases with insufficiency The corresponding values in our material were 74 per cent and 40 per cent respectively This implies that the residual volumes were considerably higher in the material of FOLSE & BRAUNWALD a difference too large to be due to a systematic error in one of the materials The percentages obtained by FOLSE & BRAUNWALD appear too low when the left ventricular volume changes are studied by angiocardiography The residual volume appears very small when compared with diastolic volume and it seems unlikely that less than 50 per cent of the diastolic volume should be expelled during systole Other investigators of angiocardiographic volume changes also found a much higher quotient for instance BRUCE & CHAPMAN observed a quotient of 76 5 per cent in normal males and BUNELL et coll 71 per cent in their paediatric material of coarctation

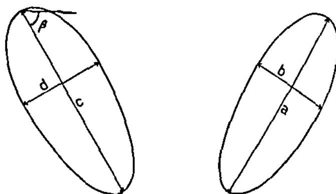


Fig. 7. Schematic representation of different methods for the angiocardiographic determination of the left ventricular volume. Antero-posterior projection (left) and lateral projection (right).

Method II (DODGE et coll.)

$$V = 4\pi/3 \cdot \frac{a}{2} \cdot \frac{b}{2} \cdot \frac{d}{2} \text{ if } a > c$$

and

$$V = 4\pi/3 \cdot \frac{c}{2} \cdot \frac{b}{2} \cdot \frac{d}{2} \text{ if } c > a$$

Method III (DODGE et coll.)

$$V = 4\pi/3 \cdot \frac{a + c}{4} \cdot \frac{b}{2} \cdot \frac{d}{2}$$

Method used for the present study

$$V = 4\pi/3 \cdot \frac{b}{2} \cdot \frac{d}{2} \cdot \frac{1}{2}(c^2 \cos^2\beta + a^2)^{\frac{1}{2}}$$

All measurements are assumed to be corrected for geometric distortion.

B. *Errors and limitations of angiocardiographic determination of insuffiency*

Angiocardiography involves several factors that interfere with the normal physiology, the contrast medium affects the circulation as does the pre-medication. General anaesthesia, which also changes the circulatory conditions, was used in the present study. General anaesthesia, however, is no longer necessary for angiocardiographic investigations, the new contrast media of the diatrizoate type have a very low toxicity and may be injected both into the left and right sides of the heart without undue discomfort to the patient. General anaesthesia is seldom used at the present time in angiocardiographic examinations in our department. But even if anaesthesia is not employed there is a considerable change in haemodynamics from the time of the Fick determination to the angiocardiographic examination, and the ideal solution would be to perform stroke volume determination of the ventricle and output analysis simultaneously. This could be achieved by an indicator dilution technique, or possibly by the method of PORJE & RUDEWALD, already mentioned. The earlier study of the left ventricular volume showed, however, that there was a relatively good correlation between the Fick and angiocardiographic determination, and the figures for insufficiency given in the present paper are without doubt fairly reliable. A disadvantage with the method is that it is very difficult to obtain examinations that fullfill all the requirements for the analysis, one of the greatest drawbacks is that cases with atrial fibrillation cannot be analyzed. The usual information from angiocardiography is obtained in the cases in which complete volume analysis is impossible: semi-quantitative evaluation of mitral and aortic insufficiency may be made by observing the regurgitation of contrast medium (BJORK, LODIN & MALERS, KJELLBERG et coll.), and the anatomy and mobility of the mitral and aortic valves may be studied directly in the films. More data are obtained than by any other method in those cases in which it is possible

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Conclusions

The end diastolic as well as the end systolic volumes are increased in cases of mitral and aortic insufficiency compared to those without insufficiency The increase in these volumes is mainly governed by the degree of insufficiency

There exists a linear relationship between the end diastolic and end systolic volumes of the left ventricle The end diastolic/end systolic volume quotient seems to be smaller in cases of insufficiency than in those without insufficiency A larger more homogenous material must be studied to prove this hypothesis

The regurgitant volume in extreme cases of mitral insufficiency may be as large as 90 per cent of the stroke volume Incompetence of that degree has not been observed in aortic insufficiency

The cardiac index is significantly decreased in cases of insufficiency as compared to those without insufficiency in the material earlier presented

The volume curve of the left ventricle in the cases of insufficiency showed no characteristic features as compared with those without incompetence The only difference was that the insufficiency curve had a higher amplitude

SUMMARY

Twenty cases of mitral and/or aortic insufficiency were studied by angiocardiography the stroke and minute volumes of the left ventricle being determined by direct measurement of the volume from the films The degree of insufficiency varied within wide limits the highest degree observed being 90 per cent regurgitation Different methods for the assessment of the left ventricular volume and the advantages and limitations of these methods are discussed

ZUSAMMENFASSUNG

Zwanzig Fälle von Aorteninsuffizienz mit oder ohne gleichzeitiger Mitralinsuffizienz wurden angiokardiographisch studiert wobei das Schlag und Minutenvolumen des linken Ventrikels durch direkte Messungen am Röntgenbild bestimmt wurden Der Grad der Insuffizienz variierte innerhalb weiter Grenzen der schwerste Fall zeigte 90 % Regurgitation Verschiedene Methoden fur die Bestimmung des linken Kammervolumens und ihre Vorteile sowie ihre Begrenzung werden besprochen

RÉSUMÉ

Vingt cas d insuffisance mitrale et/ou aortique ont été étudiés par angiocardiographie le volume systolique et le débit par minute du ventricule gauche étant déterminés par mesure directe des volumes sur les films Le degré d insuffisance variait dans de larges limites le degré le plus élevé observé étant de 90 pour cent de régurgitation Les auteurs étudient différentes méthodes de mesure du volume ventriculaire gauche et en examinent les avantages et les limites



Fig 1 Cas 1 Axial view of the base of the skull Poo ly defined dentate bony defect at the t p of right petrous pyramid Porus acusticus internus not widened No calcifica t o s in area of tumour

from 2 to 8 years Chondromas of the pontine angle have been the commonest of the chondromas of the posterior fossa only one chondroma situated in the clivus has been reported (KLINGLER 1951)

Case reports

Case 1 Woman aged 6? with gradual loss of hearing in the right ear over several years Two months before admission she suddenly developed headache nausea severe vertigo and right sided facial paralysis

Roentgen examination of the skull disclosed a poorly defined dentate bony defect at the tip of the right petrous pyramid the porus acusticus internus was not widened No calcifications were seen in the area of the tumour

Encephalo aphy revealed evidence of a tumour of the right pontine angle The right ponto cerebellar cistern was deformed and displaced cranially and medially while the right cis terna ambiens and cisterna medullaris were dilated deformation of the lateral margin of the pons was evident The fourth ventricle and the aqueduct lay in the midline and were not displaced upwards the lateral ventricles were symmetrically located and slightly widened

No pathologic vessels v ere establ shed on *vertebral angiography* by which only a lateral projection was obtained

The patient died from pulmonary embolism 9 days after partial extirpation of the tumour It was established at operation and at autopsy that there was a large smooth surfaced solid tumour at the right pontine angle which bulged towards the tentorial notch close to the hypophysis its caudal part extending almost to the foramen magnum The tumour also pene trated the base of the skull so that a pair of scissors could readily be passed into the pharynx at autopsy

Histologic examination disclosed a chondroma (V Ritama)

Case 2 Man aged 57 whose hearing had deteriorated over 4 years and who had occa s onally had double vision

Roe tg n examin tion of the skull revealed a poorly defined dentate bony defect at the tip of the left petrous pyramid extending posteriorly to the region of the porus the porus acusticus internus was not w dened No calcifications were evident in the area of the tumour

FROM THE NEUROSURGICAL CLINIC (DIRECTOR: PROF. G. AF BJÖRKESTEN) OF THE UNIVERSITY OF HELSINKI, TÖÖLÖ HOSPITAL, HELSINKI, FINLAND

ROENTGENOLOGIC FINDINGS IN CHONDROMAS OF THE PONTINE ANGLE

by

MAURI ROUKKULA

Chondromas of the base of the skull are rare. Four such chondromas were reported to have occurred (LEITHOLF 1956) in a series in 4 399 brain tumours from the neurosurgical clinic of Serafimerlasarettet, Stockholm. None of them, however, was a chondroma of the pontine angle which the present author, like KLEINSASSER & FRIEDMANN (1958), considers to be the only typical location of infratentorial chondromas.

Parasellar chondromas of the type growing partially into the posterior fossa were not included in this study because supratentorial chondromas are clinically very different from infratentorial chondromas.

A total of 7 chondromas of the pontine angle have been described (HIGIER 1922, FALKENBERG 1941, KLINGLER 1951, SCHULZE 1954 and KLEINSASSER et coll.). Six of the tumours lay in the left and one at the right pontine angle; they were generally large, ranging from the size of a plum to that of a hen's egg. Four of the patients were women and 2 men; no mention was made of the sex of one patient. The ages ranged from 37 to 69 years, the mean age being 48 years; no age given for one patient. The duration of the symptoms before admission was generally long and in the 5 cases in which it was given it ranged

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Fig 3 Same case as in figs 1 and 2 Photomicrograph of chondroma × 120 No calcifications

the roentgen examination in two of these was inadequate and no destruction was demonstrated but the apex of the pyramid was found at autopsy to be destroyed in one of them It would appear from the operative findings and autopsy that at least in 3 cases described in the literature the origin of the tumour was in the medial part of the posterior wall of the petrous bone It is however difficult to determine the origin of the tumour if the bone destruction is extensive (CASTELLANO et coll 1953)

No widening of the porus or meatus acusticus internus was established in 2 cases in the literature or in the present cases It was not possible to assess the size of the porus in 2 cases because of an inadequate roentgenologic examination Slight widening of the porus or meatus acusticus internus was described in 2 cases (FALKENBERG KLEINSASSER et coll)

2 *Tumour calcifications* Calcification was demonstrated in the tumour in 5 out of 6 chondromas of the middle cranial fossa reported by KLEINSASSER et coll Roentgenologically verifiable calcification was observed in 14 of the 16 primary intracranial chondromas reported by KLINGLER Calcifications are thus fairly common in chondromas of the middle fossa A fine reticular cal

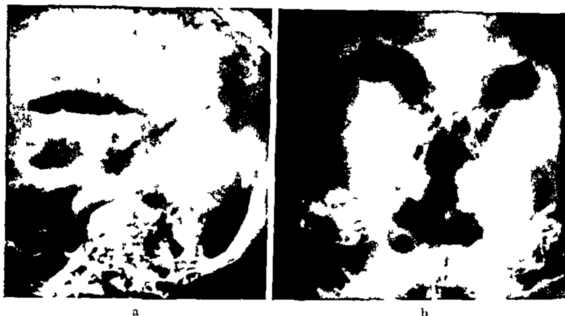


Fig 2 Case 1 Same case as in fig 1 a) Lateral view of posterior fossa No pathologic changes b) I a view The right ponto cerebellar cistern is deformed by the tumour and displaced cranially and medially ipsilateral cisterna ambiens and cisterna medullaris widened No lateral displacement of the third and fourth ventricles

Encephalography suggested the presence of a tumour in the left pontine angle The left ponto-cerebellar cistern was deformed and displaced cranially and medially The air in the cistern surrounded a tumour node of thumb tip size which was rounded in contour and sharply circumscribed The left cisterna ambiens and cisterna medullaris were widened and the left margin of the pons was deformed The aqueduct and fourth ventricle were not markedly displaced upwards and no lateral displacement was observed The lateral ventricles were symmetrically positioned and slightly widened

Vertebral angiography disclosed no pathologic blood vessels in the area of the tumour The basilar artery near the middle of the clivus described a posteriorly directed bend

Exploratory craniotomy revealed a solid tumour with adherent small nodes in the left posterior fossa *The medial part of the tumour extended to the foramen magnum* while its lateral part ran from the region of the foramen jugularis down past the acoustic nerve

Histologic examination of biopsy specimen Chondroma The patient was up and about at the follow up examination half a year later He had no headache but complained of pain in the left arm

The roentgenologic appearances produced by chondromas of the pontine angle may be divided as follows

1 *Bony destruction* A bony defect was established at the apex of the petrous pyramid in two cases reported in the literature and in both the present cases *The defect extended in the former cases to the medial surface of the pyramid* as far as the porus, the defect in the latter cases was dentate and ill defined

Atrophy at the apex of the pyramid is described in 3 cases in the literature,

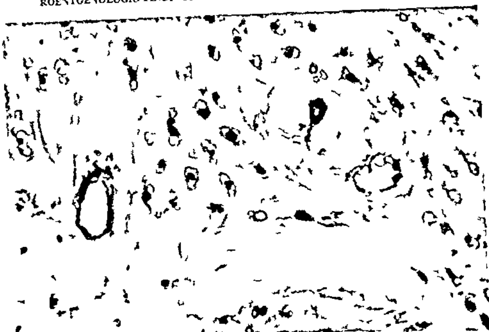


Fig 5 Same case as in fig 4 Photomicrograph of chrondroma × 220 No calcifications evident

Differential diagnosis

Acoustic neurinoma Differing from the chondromas of the pontine angle most acoustic tumours cause widening or destruction of the meatus acusticus internus (e g LASSILA 1937) LINDGREN (1954) stated that only an acoustic neurinoma causes unilateral widening of the porus and this sign may consequently be regarded as pathognomonic of acoustic tumours KLINGLER considered the occurrence of calcification in a chondroma of the pontine angle to be of significance in the differential diagnosis of acoustic neurinoma This however, is not in conformity with the fact that it has not been possible to demonstrate calcifications in any chondroma of the pontine angle so far established not even in KLINGLER's own case As regards displacement of the aqueduct and the fourth ventricle the encephalographic findings in the present cases are not so marked as the corresponding changes demonstrable in connection with a large acoustic neurinoma (LILIEQUIST) Typical ellipsoid tumour capsule blood vessels (YASARGIL 1962) and pathologic blood vessels in the tumour area (LINDGREN) may be encountered in acoustic neurinoma Such changes were not observed in the present cases

Meningioma The commonest situation of meningiomas of the posterior fossa is the pontine angle (CASTELLANO et coll) Calcification of the tumour, bony



Fig 4 Case 2 Lateral vertebral angiography The basilar artery describes a bend near the middle of the clivus no pathologic blood vessels in the area of the tumour

cification was evident in a chondroma of the clivus in one of KLINGLER's cases No calcification was however demonstrated, in the literature or in the present series, in any case of chondroma of the pontine angle This may in part be because it is more difficult to demonstrate a calcification in the posterior fossa than in the middle fossa It is also possible that no roentgenologically verifiable calcifications occur in chondromas of the pontine angle

3 *Pneumographic changes* Typical encephalographic changes due to a tumour of the pontine angle (LINDGREN 1950, LILIEQUIST 1959) were found in both the present cases The ipsilateral pontocerebellar cistern was deformed by the tumour and the ipsilateral cisterna medullaris and cisterna ambiens were dilated, deformation was evident on the tumour side of the pons The aqueduct and fourth ventricle lay in the midline KLEINSASSER et coll reported that in one of their cases examined by ventriculography the aqueduct and the fourth ventricle were displaced posteriorly and superiorly This change was not established with certainty in the present case material

4 *Vertebral angiography findings* The vertebral angiography findings in connection with chondroma of the pontine angle do not appear to have been previously described No pathologic blood vessels were observed in the present cases The basilar artery in Case 2 ran in a bend backwards near the centre of the clivus, but no other displacements of the vessels were established

Conclusions

The following conclusions appear to be warranted in spite of the small material Chondromas of the pontine angle are generally large tumours of slow growth Large scale roentgenologic changes are often associated with the long history of the condition Bone destruction which is typical of pontine angle chondromas, is located at the apex and posterior surface of the petrous pyramid, and seems to occur lower down than the bony changes arising with most of the other tumours that may be present in this region e g meningiomas The boundaries of the bone defect are dentate and poorly defined There is no marked widening in the porus or meatus acusticus internus It has not been possible to demonstrate calcifications in the cases of chondroma of the pontine angle reported so far As regards displacement of the aqueduct and the fourth ventricle the encephalographic changes are not as marked as those produced by other large tumours of the pontine angle No pathologic blood vessels in the tumour area are demonstrable on vertebral angiography

SUMMARY

The roentgenologic findings in two cases of chondroma of the pontine angle are described and the differential diagnosis of other tumours in the region of the pontine angle with special reference to the encephalographic and angiographic appearances is discussed

ZUSAMMENFASSUNG

Die Röntgenerscheinungen in zwei Fällen von Chondrom des Kleinhirnbrückenwinkels werden beschrieben Die Differentialdiagnose wird *mit Hinsicht* auf die encephalographischen und angiographischen Symptome erörtert

RÉSUMÉ

L auteur décrit les signes radiologiques de deux cas de chondrome de l angle ponto-cérébelleux et étudie le diagnostic différentiel des autres tumeurs de la région de l angle ponto-cérébelleux en insistant particulièrement sur les images encephalographiques et angiographiques

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destruction and changes in the structure of the petrous bone, especially sclerosis and new bone formation, were observed in some of their cases. Neither tumour calcification nor the above changes in bone structures have been demonstrated in pontine angle chondromas, in which the destructions seem to be lower down in the petrous pyramid than the bony changes caused by meningiomas, even in these tumours the encephalographic changes were more marked (LILIEQUIST) than in the present cases. Profuse vascularization may on vertebral angiography be fairly frequently established in meningiomas of the pontine angle (YASARGIL).

Cholesteatomas of the pontine angle, *unlike chondromas*, cause no typical changes in bones (OLIVECRONA 1949).

Chordomas arise from the clivus and grow towards the pontine angle, while the direction of growth of chondromas is generally the opposite (KLEINSASSER et coll.). Chordomas usually affect the clivus, sella turcica and apex of the petrous pyramid (LINDGREN & DI CHIRO 1951), while the bone destruction caused by pontine angle chondromas occurs in the posterior wall and apex of the petrous pyramid. Chordomas often show evidence of calcification (LINDGREN et coll.), chondromas of the pontine angle are never calcified.

Bony destruction caused by a trigeminal neurinoma is sharply circumscribed, and in conformity with the site of origin of the tumour destruction is demonstrable *especially at the impressio trigemini and in the region of the foramen* ovale and spinosum (LINDGREN 1941). These tumours, when they grow into the posterior fossa, cause a defect either at the apex of the petrous pyramid or in its posterosuperior part (LINDGREN) and in addition cause typical encephalographic changes in the temporal horn (LINDGREN 1948). Trigeminal neurinoma may be distinguished from chondroma of the pontine angle by the aforementioned sharply circumscribed destruction and by encephalographic findings. Pathologic blood vessels may be demonstrated in trigeminal neurinoma on vertebral angiography (LINDGREN, YASARGIL).

Hypoglossal neurinomas produce a clearly circumscribed defect at the inferior aspect of the petrous pyramid (RAUSCH 1956), which, in keeping with the site of origin of the tumour, is located further back than the changes produced by a chondroma. Vascular tumours of the pontine angle, glomus tumours and angioblastomas may be distinguished from chondromas by the profuse pathologic vascularization demonstrable on vertebral angiography (YASARGIL). A subarachnoid cyst, unlike chondromas may cause non filling of the ipsilateral ponto cerebellar cistern on encephalography but in the other cisterns (LILIEQUIST) no changes are observed.

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ANGIOGRAPHIC DIAGNOSIS OF INTRACEREBRAL VASCULAR OCCLUSIONS

by

I O TANNER and K ROSENGREN

Recent progress in the treatment of cerebral ischemia has increased the interest in the accurate diagnosis of the causal conditions Stenoses and occlusions of cervical vessels are in many cases accessible to surgical treatment

Experiments with drugs such as fibrinolysin and streptokinase that can disintegrate thrombi, have in late years promised a successful approach to occlusions of intracerebral vessels These are very potent agents and their use requires an exact determination of the condition to be treated

The clinical diagnosis of occlusion of an intracerebral artery is often difficult, and in a great many cases it can be stated only that occlusion is probable The difficulty was particularly evident in an investigation based on an autopsy material by YATES & HUTCHINSON (1961) who selected 100 cases with signs suggesting cerebral ischemia as the cause of death No cases with clinically diagnosed intracranial hemorrhage were included in the material, but in spite of this intracerebral hemorrhage was found at autopsy in 28 cases

According to DECKER (1958) a stroke is caused five times more often by infarction than by hemorrhage A great many cases in the former group might be intensively treated with anticoagulants if the diagnosis could be definitely

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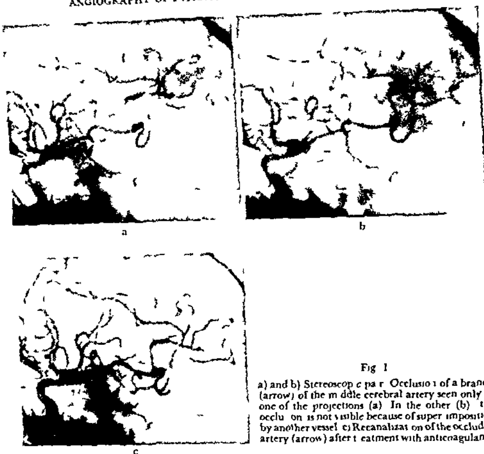


Fig 1

a) and b) Stereoscopic pair Occlusion of a branch (arrow) of the middle cerebral artery seen only in one of the projections (a) In the other (b) the occlusion is not visible because of superimposition by another vessel c) Recanalization of the occluded artery (arrow) after treatment with anticoagulants

in 8 the artery of the angular gyrus in 7, and the posterior temporal artery in 3 cases More than one occlusion was found in 6 cases

The anterior cerebral artery was thrombosed in 2 cases, in 3 cases *the* thrombus was situated in the pericallosal artery or one of its branches A thrombus in the posterior cerebral artery was found in 3 cases

Films were obtained of the cervical region in 16 cases this making it possible specifically to examine the common carotid artery and its bifurcation In 11 of these cases the vessels had slight arteriosclerotic changes and in only 5 cases normal angiographic appearances Marked narrowing was evident in 2 cases One of these had considerable stenosis of the external carotid artery near its origin from the common carotid artery in the other advanced arteriosclerotic narrowing *of the internal* carotid artery near the bifurcation, known from a previous angiography was demonstrated and in addition there was total occlusion of the middle cerebral artery

established. The eventual functional restitution of infarcted cerebral tissue is of course slight, but the correct treatment may limit and reduce the extent of a lesion, and possibly prevent further damage.

Material and Methods

Twenty six cases (of which 17 were male and 9 female) of intracerebral occlusion have been diagnosed by carotid angiography at our clinic during the years 1960 and 1961. (Cases of thrombosis of the extracranial part of the carotid artery are excluded.) The age distribution was as follows: 5 cases were under 40 years of age, 4 between 40—50, 4 between 50—60, 8 between 60—70, and 5 were over 70 years of age. The average of the ages, 54.8 years, is rather low. Only a small number of cases with clinical signs of stroke were examined, and there was some selection on the basis of age, with a preference for younger subjects for angiography.

Six cases had had previous neurologic signs, probably due to cerebral ischemia, two had had headache for many years, and two cases had been treated for psychic disturbances. There was insufficient information regarding the past history in one case and no history of previous neurologic signs in fifteen. Ten of the cases had a systolic blood pressure of over 160 on admission. Four of the cases were of chronic valvular cardiac disease with auricular fibrillation and in two cases arteriosclerotic heart disease had been diagnosed. The interval between the onset of acute symptoms and angiography varied. Twelve cases were examined within 24 hours of the first symptoms, in two cases 4 days elapsed, and in eleven cases more than one week, before angiography.

The contrast medium was injected by needle in most cases and only when treatment with fibrinolysin had been planned was a catheter used. It has usually been possible to exclude thrombosis of the carotid artery by means of a low puncture of the common carotid artery before examination of the intracranial vessels. In eleven cases, the intracranial vessels were too poorly filled to be examined after injection of contrast medium into the common carotid artery, the internal carotid artery was then punctured. A polythene catheter was used in catheterization by the Seldinger method, the contrast medium was 5 to 6 ml Urografin 45 % and an Elema AOT filmchanger was employed both for the lateral and a. p. projections.

Stereoscopic films were obtained in some cases, alternating exposures being made with two tubes, with an angle of 6° between them, after the medium had been injected. Rapid film changing is necessary if two films are to be obtained in as nearly as possible the same circulatory phase.

Results

There was occlusion of the main stem of the middle cerebral artery in 6 cases. The frontal ascending artery was occluded in 3, the posterior parietal artery

occlusions was apparent in 2 cases although in spite of the circulatory improvement a regression of the neurologic symptoms was evident in only one of them

One of the subjects with total occlusion of the middle cerebral artery who was not reexamined died two months after angiography No thrombus was found at autopsy but there was a large area of cerebral softening corresponding to the region fed by the middle cerebral artery This might perhaps explain wholly or in part YATES & HUTCHINSON's finding of infarction in 16 cases but no obvious obstruction of the intracerebral vessels (only of the extracerebral arteries)

Certain criteria may be laid down for the diagnosis of an intracranial arterial occlusion an abrupt halt to the contrast filling of an artery combined with avascularity of the region and/or filling of the vessel in a retrograde direction via anastomoses Such an obstruction was encountered in 20 of the present cases Occlusions situated in large arteries some distance distal to a major bifurcation seldom offer any diagnostic problem and is particularly true of middle cerebral artery occlusions A distinct cessation of the filling is in suitable projections almost always apparent in these cases If however, an artery is occluded close to a bifurcation the diagnosis may be difficult Detection of thrombosis in a thin vessel may present a special problem and demand a modified technique and the necessary equipment

The examination of peripheral branches requires complete filling with contrast medium It appears to the writers that this is best achieved by injection of contrast medium directly into the internal carotid artery overprojection of branches of the external carotid artery is then also avoided In angiography both in lateral and anteroposterior projections branches of the intra cerebral vessels are projected over each other and this makes it difficult or impossible to determine the course of a vessel and separate it from other vessels of the same size Stereoscopy by which as a rule it is possible to separate the different branches may be most useful in these cases Occlusion of a rather wide artery was in one case completely hidden by superimposed vessels and could be seen only in one of the stereoscopic projections (Fig 1)

Retrograde arterial filling peripheral to an occlusion by way of lepto meningeal anastomoses was encountered in all but one case The contrast medium in this case had been injected into the common carotid artery and the intracerebral vessels were too poorly filled for definite conclusions to be drawn Retrograde filling can be ensured only if the film series is so timed that the filling of the arteries can be followed This may be accomplished by obtaining at least 2 films per second for about 4 sec and then another 4 to 6 films at 1 sec intervals The late films are obtained because of the slow circulation through vessels with reversal of flow (Fig 2)

Thrombosis in the central parts of the anterior and posterior cerebral arteries may not be readily diagnosed Failure to demonstrate these vessels

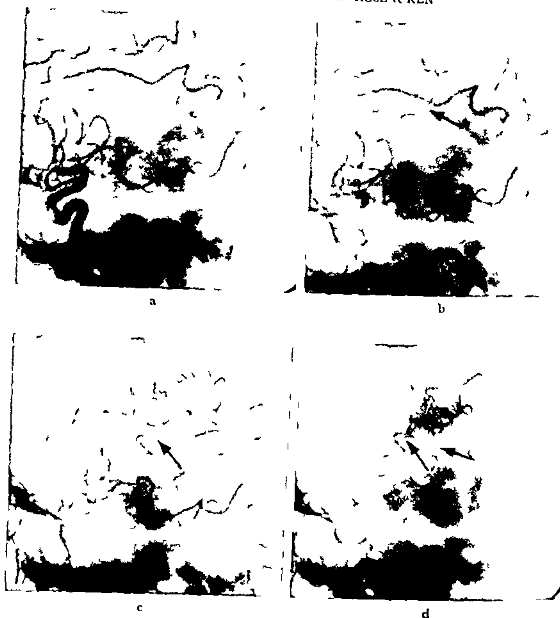


Fig 2 Retrograde contrast filling of two branches (arrows) of the posterior parietal artery peripheral to the occlusion one of these filling later than the other Stereo copic series a) at 1 sec b) at 2 sec and d) at 4 sec after injection and all in one projection c) At 2 5 sec in the other projection

Three of the 10 cases, in which only the internal carotid artery was examined, were found to have small arteriosclerotic changes in the extracranial portion of this artery The vessel was normal in appearance in the remaining 7 cases

Eight cases with proved occlusions of intracerebral arteries were treated with fibrinolysin injected through a catheter with its tip in the internal carotid artery (This treatment was given only during 1961) Five of these cases were subjected to follow up angiography Recanalization of previously proved

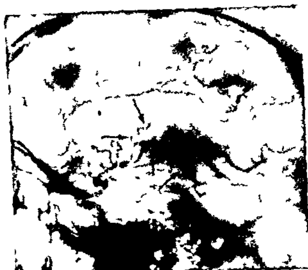


Fig 4 Rap d passage of the contrast medium to the central eins (arrow) in a case with occlus on of th posterior parietal artery

It would appear evident that it is a rule in all cases of intracerebral thrombosis that the vessel peripheral to the occlusion will be filled in retrograde direction via anastomoses

The writers consider retrograde filling to be so reliable a criterion that the failure in its demonstration demands an explanation this may be found in spasm or the needle point having been placed partially in the vessel wall No obvious association between retrograde filling and the time of the thrombus or the age of the subject has been noted It is quite probable that these pial (leptomeningeal) anastomoses take part in a collateral circulation as soon as the occlusion occurs

A 66-year old woman was examined as early as 6 hours after the onset of symptoms and was found to have an occlusion of the middle cerebral artery, with filling of the peripheral branches of the occluded vessel from anastomoses In another case an initial film of the neck revealed that the middle cerebral artery was filled but a small defect, probably an embolus was present in one of its branches Later in the complete series of films this vessel failed to fill in the ordinary way but there was retrograde filling of the peripheral branches

The pial anastomoses probably begin to function when there is a pressure gradient in a region supplied by different arteries This is shown by a case with a large arteriovenous aneurysm fed by the middle cerebral artery Some of the peripheral branches of this vessel were filled in a retrograde direction from the posterior cerebral artery There had probably been a lower pressure in the peripheral part of the middle cerebral artery than in the posterior part in which the retrograde flow was initiated

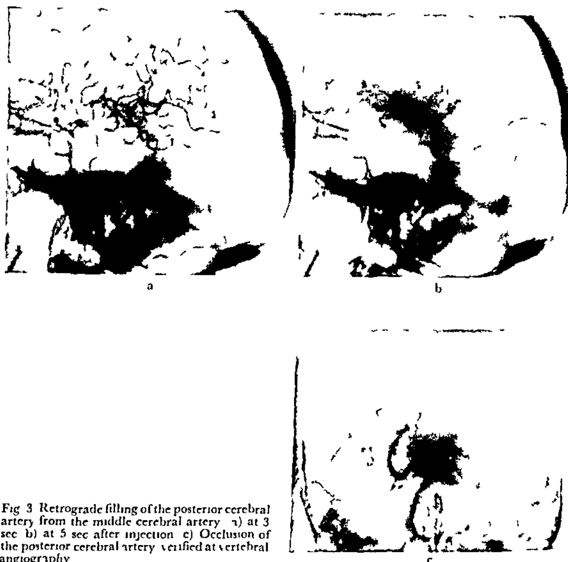


Fig 3 Retrograde filling of the posterior cerebral artery from the middle cerebral artery a) at 3 sec b) at 5 sec after injection c) Occlusion of the posterior cerebral artery verified at vertebral angiography

may depend on the flow of blood during the exposure periods coming from the contralateral hemisphere through the anterior communicating artery, or from the basilar artery to the posterior cerebral artery Anatomical variations, which will render interpretation difficult, are also not uncommon in this region

The demonstration of reversed circulation in the peripheral parts of the anterior or posterior cerebral arteries may thus be the only dependable angiographic criterion of an occlusion *A retrograde flow of contrast medium from* anastomoses has been a decisive factor in the diagnosis in all the cases of thrombosis in the posterior and in the anterior cerebral artery Vertebral angiography verified the diagnosis in one of the cases with thrombosis of the posterior cerebral artery (Fig 3)

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Very early passage of contrast medium to the central veins was recorded in 5 of the 20 cases with thrombi in the middle cerebral artery The veins in these cases were already filled during the arterial phase, in two cases the veins filled during the early arterial phase while contrast medium still remained in the carotid siphon The cause of this early passage to the central veins is not clear but would appear to depend in some way on the occlusion, it may even be the result of a collection of acid metabolites causing vasodilatation One of these subjects, a 30 year-old man with no evidence of previous disease, suddenly developed aphasia and right sided hemiparesis Angiography showed occlusion of the posterior parietal artery and very rapid passage of contrast medium to the central veins (Fig 4), which were filled early in the arterial phase Repeat angiography two months later, when the patient had almost completely recovered, revealed that the occluded artery was recanalized The central veins then filled at the usual time, that is 7 to 8 sec after the injection of the contrast medium

SUMMARY

The diagnosis of intracerebral vascular occlusion in a material of 26 cases is reported Retrograde filling of an artery via pial anastomoses was a constant finding in all the cases Rapid passage of contrast medium to the central veins was observed in 5 of the cases in which there were thrombi

ZUSAMMENFASSUNG

Die Diagnose von intracerebralem Verschluss der Hirngefässe in 26 Fällen wird berichtet Die retrograde Füllung einer Arterie durch Anastomose mit den Pia Gefässen war ein konstanter Befund Ein rascher Übertritt des Kontrastmaterials in die zentralen Venen wurde in 5 Fällen beobachtet bei denen Thromben vorlagen

RÉSUMÉ

Les auteurs rapportent 26 cas de diagnostic angiographique d obstruction vasculaire intra cérébrale L opacification rétrograde d une artère par des anastomoses pie mériennes a été constatée dans tous les cas Le passage rapide du moyen de contraste vers les veines centrales a été observé dans 5 cas ou il y avait des thrombus

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tissue had been removed from the same region on one or several occasions Nine of the patients are represented twice in the material so that the results cover a total of 101 examinations in 92 patients The age distribution is given below

Age in years	Patients
20—29	2
30—39	24
40—49	47
>50	19
	Total 92

Roentgenographic evaluation Those reviewing the films for the purpose of the investigation were unaware of the clinical or operation findings The roentgenographic evaluations however, were compared with previous descriptions if available only insignificant discrepancies were found

The interpretation of a myelogram is generally simple in subjects who have not undergone previous operation, provided an adequate examination has been performed In those who have previously undergone laminectomy however the appearances are difficult to interpret the difficulty consisting in distinguishing the sequelae of operation or changes in the structure of the arachnoid membrane from alterations caused by prolapse or protrusion

Results

The myelographic and operation findings are compared in Table 1 The evaluation of the latter rests exclusively on the operation reports The roentgenographic difference between protrusion and prolapse is a debatable one The term protrusion has been reserved to describe flattened bulges in the subarachnoid space medially and at a level with the disks as shown in a lateral projection while the term prolapse has been reserved for the large median and anterolateral bulges

It will be seen from Table 1 that a diagnosis of prolapse made on the basis of the roentgenogram was verified by operation in 66 % of the patients if no distinction is drawn operatively between prolapse and protrusion agreement was found in 79 % Similarly a roentgenologic finding of protrusion was confirmed by operation in 47 % of the patients and if no operation distinction is made between prolapse and protrusion this percentage is increased to 67 % If no distinction is drawn either roentgenographically or operatively between prolapse and protrusion the myelographic findings were confirmed in 75 % of the patients

The myelographic findings in three patients were such as to prevent them being grouped in Table 1 Myelography in one of these revealed a large expanded dural sac without recognizable root sheaths operation disclosed root

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MYELOGRAPHY WITH WATER-SOLUBLE MEDIA IN LUMBAGO-SCIATICA AFTER OPERATION FOR HERNIATED LUMBAR DISK

by

A. FAHRENKRUG, B. GOTTSCHALCK and K. HØJGAARD

Myelography by water soluble positive contrast media, since the method was introduced in 1931, has been increasingly employed in patients with probable herniated lumbar disk, especially in those considered suitable for operation. Some patients have had to undergo operation repeatedly, either because of indications of a new herniation or of recurrence of the original condition. An evaluation of the myelograms has however produced some uncertainty as to how much weight may be attached to any deviations from the normal appearances. It was therefore considered of interest to compare the myelograms and the operation findings in a number of patients operated on previously for herniated lumbar disk and presenting further symptoms.

Material. The material consists of 92 patients, 38 of whom were women and 54 men, operated on during the period 1953—1960 for probable herniated lumbar disk. All patients had been subjected to previous operation and disk

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Table 2

Group A 72 patients with adherent intraspinal scar tissue

Main findings at myelography	*Corresponding operation findings*
38 prolapse	20 prolapse 6 protrusions 12 root adhesions only
12 protrusions	0 prolapse 7 protrusions 5 root adhesions only
16 root shortening (no certain sign of prolapse)	6 prolapse 1 protrusion 9 root adhesions only
6 normal conditions	0 prolapse 3 protrusions 3 root adhesions

Group B 26 patients without adherent intraspinal scar tissue

19 prolapse	17 prolapse 1 protrusion 1 large epidural veneplexus
3 protrusions	3 prolapse
3 root shortening (no definite evidence of prolapse)	2 prolapse 1 protrusion
1 normal condition	1 protrusion

gave a clear indication of the side In group B 26 patients without adhesions, the corresponding agreement is 80 %

If the small group of patients who were operated upon three or even four times is considered it is found that agreement between the myelograms and the operation findings is not so good as in the remaining material The results are presented in Table 3 If comparison is made between earlier myelographic and operation findings in these patients, less agreement than in the other material is likewise apparent

If the entire material is divided into two groups the one containing the 60 patients who had undergone previous myelography and the other group consisting of the patients who had not been so examined operatively verified adhesions were evident in 76 % of the first group and in 68 % of the second group

Discussion

Agreement between the roentgen and operation findings may be evaluated for all those patients examined except for three patients in Table 1 As anticipated the agreement is best when myelography demonstrated a prolapse

Table 1

Main findings at myelography	*Corresponding operation findings*
14 prolapse − root shortening	5 prolapse 4 with root adhesions 2 protrusion 2 with root adhesions 7 root adhesion only
43 prolapse + root shortening	32 prolapse 16 with root adhesions 5 protrusion 4 of these with root adhesions 5 root adhesions only 1 large epidural veneplexus
9 protusion − root shortening	5 protrusion all with root adhesions 1 prolapse 0 root adhesions 3 root adhesion only
6 protrusion + root shortening	2 protrusion both with root adhesions 2 prolapse 0 root adhesions 2 root adhesion only
19 only root shortening (no diagnosis of prolapse)	8 prolapse 6 with root adhesion 2 protrusion 1 with root adhesions 9 root adhesion
7 normal conditions	0 prolapse 4 protrusion 1 with root adhesions 3 root adhesion

adhesion caused by scar tissue The other two patients had large coherent bulges in the column of contrast medium, behind the bodies of the vertebrae, prolapse of the 3rd vertebral disk was found at operation in both

The material is divided into two groups in Table 2 Group A consists of patients who had adherent scar tissue on operation and group B of patients in whom no mention of adhesions was made in the operation report

The following agreement between the roentgen findings and operation report is apparent in group A If the roentgen appearances indicated prolapse, there is agreement in 63 % of the patients and if no operation distinction is drawn between prolapse and protrusion, the agreement is increased to 68 % If the roentgen appearances indicated the presence of protrusion, there is agreement in 58 % of the patients There is no operation prolapse in this latter group

The agreement in group B is as follows With prolapse indicated in the roentgenogram, there is 89 % agreement between the roentgen and the operation findings, and with no operation distinction between prolapse and protrusion there is 95 % agreement

Groups A and B of Table 2 have been examined to determine the influence of the presence or absence of adhesions on the agreement between the findings as far as the side of localization of the lesion is concerned In group A, 72 patients with verified adhesions, there is 69 % agreement as to the side of localization if only those are included in whom the myelographic examination

of scar tissue When operation had not revealed the presence of such tissue agreement approached that found in patients who had not been operated upon previously

As anticipated, poor agreement existed between the myelographic and operation findings in patients operated upon three or four times, similar poor agreement at the previous operations was however evident in these patients It may be that such patients represent a special group of scar tissue producers

Conclusion

Myelography with a water soluble contrast medium showed good agreement with the operation findings in 65 % of patients with lumbago sciatica who had previously been operated upon for herniated lumbar disk The best agreement between the myelographic and the operation findings was obtained where myelography had shown prolapse although a negative myelogram cannot, of course exclude the presence of a lesion Confirmation was obtained for the observation that adhesions due to scar tissue give rise to uncertainty in the roentgenologic determination of the condition Side localization was established more correctly in the patients in whom definite evidence of prolapse was available An unequivocal diagnosis is difficult in patients in whom only root shortening is apparent although with the finding of multiple root shortening, the presence of scar tissue is extremely probable

SUMMARY

Myelography with a water soluble contrast medium showed good agreement with the operation findings in 65 % of a material of 92 patients with lumbago-sciatica who had previously been operated upon for herniated lumbar disk Myelographic evidence of prolapse improved the agreement and established the side affected more accurately Adhesions due to scar tissue produced uncertainty in the roentgenologic diagnosis

ZUSAMMENFASSUNG

Die Myelographien mit wasserloslichem Kontrastmittel zeigten gute Übereinstimmung mit den Operationsbefunden in 65 von 92 Patienten mit Lumbago-Ischias die vorher fur lumbale Diskusprotrusion operiert worden waren Die myelographischen Befunde eines Diskusprolapses zeigten besonders gute Übereinstimmung und lokalisierten die Seite genauer Adhasionen durch Vernarbungen machten die rontgenologische Diagnose unsicher

RÉSUMÉ

La myélographie avec un moyen de contraste hydrosoluble a concordé avec les constatations opératoires dans 65 d une série de 92 malades atteints de lombo-sciatique qui avaient été opérés pour hernie discale lombaire Les signes myélographiques de prolapsus discal améliorent cette concordance et indiquent de façon plus précise le coté atteint Les adhérences dues a un tissu cicatriciel rendent le diagnostic radiologique incertain

Table 3

Nine patients operated upon three or more times

Main finding at myelography	*Corresponding operation findings*
5 prolapse	3 prolapse 2 with root adhesion 2 root adhesions only
1 protrusion	1 root adhesion only
1 root shortening	1 prolapse with root adherent scar tissue
1 normal myelogram	1 protrusion
1 large expanded dural sac without recognizable root sheaths	1 root adhesion only

although it is not quite as good as that found in a material of patients most of whom had not undergone previous operation. FRIBERG & HULT (1951) found agreement in 95 % of patients in such a material, although it is true that in a material of 62 patients with negative myelographic findings operation revealed herniated disk in more than half of them. A somewhat unusual finding was that of KNUTSSON (1949). In three patients who had had a previous operation, myelography revealed evidence of prolapse, although further operation failed to verify the condition, on the other hand adhesions due to scar tissue were demonstrated in all three. HIRSCH (1958) found an agreement of 90 % in a group of patients not previously operated upon for herniated disk. Herniation of the disk was demonstrated in 40 % of patients with negative myelographic findings. JOHANSSON (1950) reported a similar positive correlation.

Greater disagreement is observed between the roentgenologic and operation findings — most marked where no abnormality was found at myelography — in the other myelographic findings listed in Table 1.

Operation disclosed pathologic changes in all patients in the group in which the only myelographic finding was root shortening, one half had prolapse, the other half scar adhesions. In contrast to CRONQVIST (1959) and DEL BUONO & FUCHS (1959), it proved impossible to find criteria by means of which could be distinguished between scar tissue and prolapse in these patients, who had previously undergone operation. The small group of patients, 12 in all, with root shortening at various levels, had nevertheless a number of adhesions, scar tissue being found in 8 of them. Even though the evidence of root shortening played a minor role in the evaluation of the myelograms in these patients, it is nevertheless possible to see from the first group in Table 1 that root shortening is a finding that supports the diagnosis of prolapse or protrusion.

As already suggested in the discussion of Table 1, a consideration of Table 2 shows that one of the causes of poor agreement between myelographic findings and operation findings, in subjects previously operated upon, is the presence

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LUMBAR MYELOGRAPHY IN COMPLETE OBSTRUCTION OF THE SPINAL CANAL

by

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Complete obstruction of the flow of contrast medium in lumbar myelography with water soluble contrast media poses difficult diagnostic problems (DEL BUONO 1957 CRONQVIST 1959, ECOIFFIER 1960 WELLAUER 1961) Massive mainly sequestrated disk herniations intradural and extradural tumours and peridural and intradural scarring may produce this condition The roentgenographic differentiation of its etiology is highly important but does not appear to have been thoroughly investigated We therefore considered that a systematic study of our available cases might be of interest

Material Only 14 cases in a total of around 1 000 myelographies performed with a water soluble contrast medium at our department presented evidence of complete obstruction 15 similar cases referred to us from other hospitals for operation brought our material up to 29 cases

Results

1 *Disk herniations* (*Fig 1*) *17 cases* Operation in all cases of this group revealed obstruction to the flow of contrast medium to be due to a large, often sequestrated disk herniation Reoperation in 4 cases showed that slight periph

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Fig 2 Postoperative scarring a) Irregularity of whole distal part of contrast column with oblique well-defined margin b) Lateral Irregular distal margin and formation mainly of posterior aspect of contrast column

2 *Chronic inflammatory changes* These may be situated extradurally, intradurally or at both sites simultaneously

Extradural chronic inflammatory scarring (Fig 2) mainly follows a surgical procedure our series included 2 cases with complete spinal obstruction due to this condition Relaminectomy in one case revealed extensive but mainly dorsally located peridural scar formation that obstructed the spinal canal at the site of the previous operation No recurrent disk herniation was present Relaminectomy had not been performed in the second case but the roentgenologic changes were highly suggestive of postoperative peridural scarring although additional intradural chronic arachnoiditis may also have been present Changes characteristic of postoperative scarring could be demonstrated at lumbar myelography Elongated irregular but sharply outlined filling defects were thus noted at the level of a vertebral body in the region of the previous laminectomy (Fig 2 a and b)

Intradural chronic arachnoiditic changes (Fig 3) were observed in 4 cases and verified at operation in 3 cases In one of these marked osteochondrosis was an additional operative finding The distal part of the dural sac in all 4



Fig 1 Different cases of complete obstruction by herniated disk a) Lateral Contrast column displaced backwards obstruction at the level of an intervertebral disk b) Concave distal border of contrast column c) Horizontal distal border of contrast column with lower margin serrated d) Oblique distal border with regular margin e) Oblique distal border with regular margin and with serrated margin widening of distal part of compressed nerve roots

eral scarring due to the previous laminectomy did not affect the dural sac Myelography with iodized oil had been performed earlier in one of these cases and residues were seen lying in the nerve root sheaths, the dural sac was not opened at operation and arachnoiditic scarring at a lower level could consequently not be excluded

Typical features could be demonstrated at myelography in all 17 cases with complete spinal obstruction due to disk herniations The level of the obstruction was situated at the height of an intervertebral space, or if the disk herniation *was sequestrated, at the level of a vertebral body, in 8 cases with sequestrated* disk herniation complete obstruction of the spinal canal was evident at a level proximal to the intervertebral disk affected The dural sac was further filled in a caudal direction dorsally or opposite to the side of the disk herniation This was best demonstrated in the lateral projection in which the dural sac was often pushed backwards, sometimes with an anterior indentation (Fig 1a) The distal outline of the sac then appeared sharply demarcated and formed an *arch with the convexity directed upwards and backwards The distal outline* in the frontal and oblique projections was sometimes slightly curved with the convexity upwards (Fig 1b) but occasionally horizontal (Fig 1c) or oblique (Fig 1, d and e) The outline generally appeared serrated on account of filling defects caused by the nerve roots and the lower part of the nerve roots was sometimes also slightly thicker than normal (Fig 1, c and e) In addition they appeared separated from each other and spread out within the dorsal sac



Fig 4 Intradural tumors a) and b) Neurinomas c) metastases Symmetric regular and well defined concave border Margin accentuated by thin area with increased density in (b) Widening of distal part of contrast column in (c) Tortuous vessel (arrows) running in a cranial direction from lower end of contrast column (a and c)

gave rise to typical roentgenologic signs The dural sac was slightly distended immediately proximal to the obstruction and a characteristic indentation in the distal part of the dural sac which gave its termination a regular sharp symmetric outline with a downward concavity was noted The border towards the tumor was accentuated by a dense thin zone of contrast medium in 4 of the 6 cases (Fig 4 b and c) and around the circumference the medium was seen to reach a lower level than the upper part of the indentation A filling defect in the contrast column due to a tortuous enlarged vessel that ran in a proximal direction from the superior aspect of the tumor was evident in two cases one a neurinoma and one a metastatic renal carcinoma (Fig 4 a and c)

The two extradural tumors angio endothelioma and reticulosarcoma presented no typical roentgenographic pattern A horizontal sharply defined but slightly serrated indentated margin was present at the site of the spinal obstruction in the case of the angio endothelioma (Fig 5a) no widening of the sac proximal to the obstruction was noted The reticulosarcoma (Fig 5b) was characterized by an elongated oblique impression against the dural sac and a considerable spread of the nerve root sheaths above the tumor



Fig 3 Arachnoiditis a) Irregular sac with eccentric defects and convex distal border b) Sac constricted distally with regular elongated defect in lateral margin convex distal border c) Irregularly deformed distal end nerve roots bunched together forming elongated some what irregular filling defects

cases was narrowed and shortened and the distal margin was convex down wards The outline of the sac was irregular with eccentric defects (Fig 3a), in one case, however, the outline was sharp and regular for a considerable distance with no filling of the nerve root sheaths (Fig 3b) Some of the nerve roots proximal to the complete obstruction were in 2 cases clustered *together* to form fusiform irregular filling defects in the contrast column (Fig 3c)

3 *Tumors* The present material includes 6 intradural and 2 extradural tumors all verified at operation

Intradural tumors (4 neurinoma, 1 ependyma and 1 metastasis) (Fig 4)

scribed by CRONQVIST in 1959 Shrinkage and shortening of the dural sac, as well as irregular eccentric contours or clear cut regular margins were noted in myelograms of cases with intradural inflammation or chronic arachnoiditis The nerve roots within the sac were seen to be bunched together DEL BUONO & FUCHS (1959) stated that intradural and extradural changes are difficult or impossible to differentiate As peridural changes mainly occur after laminec tomy a previous operation is in favour of postoperative scarring A differenti ation of obstruction due to an expansive process is easily made by reason of the typical changes

The distal margin of the dural sac was oblique, horizontal or arched with a convexity upwards in obstruction caused by a herniated disk Serration of the margin of the sac was often evident Filling of part of the dural sac opposite the side of the herniation for a considerable distance downwards was of special differential significance These changes differed from those noted in cases of intradural tumors in which the medium lay around the circumference of the sac at about the same level beneath the superior aspect of the tumor A more or less marked upwardly convex regularly outlined indentation in the distal part of the dural sac was also evident in cases of tumor the sharp out line of the filling defect was accentuated by a thin area of increased density never met with in cases of herniated disks

Another sign characteristic of tumors was a widening of the dural sac proximal to the obstruction An enlarged tortuous vessel lay proximal to the obstruction in 2 cases of intradural tumor, this was never observed in obstruc tion caused by any other lesion and may therefore be considered a characteristic diagnostic sign

A herniated disk and a well localized extradural tumor present identical appearances as might be expected since both push the dural sac aside and compress it from the outside If the compression is confined to the anterior aspect of the sac a herniation is probably present and this may be evidenced by skeletal changes such as narrowed invertebral space or localized spondylitic changes An accurate diagnosis is however not possible

The changes in the one case of extradural tumor extending over several vertebral bodies bore no resemblance to those noted in the case of a well defined localized extradural tumor or to those evident in intradural tumors or herniated disks The elongated regular impression in one aspect of the dural sac rather suggested inflammation Contrast filling of the nerve root sheaths was however apparent and these appeared to be stretched and displaced by the tumor there is usually no filling of these sheaths or, if filled in inflammatory conditions they appear irregularly deformed

Total obstruction of the lumbar spinal cord may be imitated by anatomic anomalities or by technical faults

The dural sac ends at the level of L5 in about five per cent of cases according to ARNELL (1948) This must not be mistaken for obstruction Contrast filling

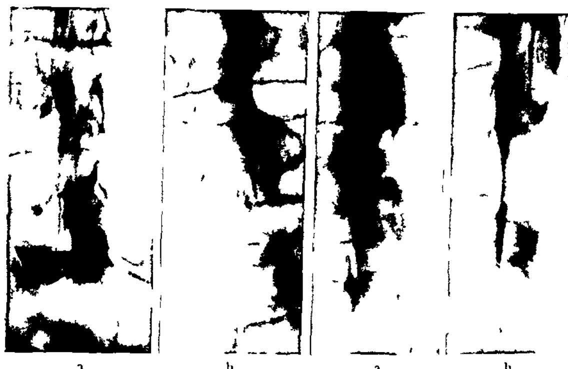


Fig. 5. Extradural tumors. a) Angioreticuloma. Sharp horizontal and well defined lower border. b) Reticulosarcoma. Atypical elongated deformation of lateral aspect of dural sac.

Fig. 6. Technical failure. a) A.p. Decreased contrast density distally simulating complete obstruction. b) Lateral. Contrast medium localized subdurally.

Discussion

Several authors (ARNELL 1948, LINDGREN 1951, REINHARDT & PANTER 1955, et alii) have described the roentgen appearances in single cases of complete spinal obstruction, evident in myelography with water soluble contrast media, although no large series appears to have been reported. However, a detailed evaluation of the findings should be possible, as the anatomic structures may *be clearly brought forward with water soluble contrast media.* This may also explain why we noted total occlusion only in about 1.4 % of cases while CAMP who used an oil contrast medium reported total blockage in 2.5 % of cases. An analysis of the present cases revealed that the pathologic conditions mainly responsible for complete obstruction: herniation, inflammatory lesion and tumor, can generally be differentiated.

Inflammatory lesions, which may be of two types — peridural following operation and intradural — present the most characteristic changes. The intradural lesions have been described following laminectomy, myelography with oily contrast agents, lumbar puncture, spinal anaesthesia, osteochondrosis and trauma.

The roentgenologic changes in the dural sac following operation were de-

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POSTGASTRECTOMY ROENTGENOGRAPHY WITH A PHYSIOLOGIC CONTRAST MEDIUM

by

POVL MADSEN and THORKILD RASMUSSEN

An aqueous suspension of barium sulphate produces little physiologic influence upon the gastrointestinal tract and is consequently unsuitable for assessing function following gastrectomy

Experiments of adding various foods to a suspension of barium sulphate have been going on for many years PENDERGRASS et coll (1936) and RAVDIN et coll (1936) included, among other nutrients hypertonic glucose and protein solutions in the barium meal They found gastric emptying to be delayed while the transit time through the small intestine was accelerated and the mucosal pattern became obliterated and blurred this was interpreted as a result of diffusion of fluid to the intestine MEURLING (1953) added milk and soups to the meal Patients who developed symptoms during the investigation proved to have the most rapid transit through the small intestine HJORTH et coll (1958) mixed barium sulphate with 150 ml glucose 50 % Of a total of 15 patients with partial gastrectomy 3 complained of symptoms of the small stomach type (pain and vomiting) 5 had typical dumping and one had postcibal diarrhoea symptoms that were reproduced during the investigation The glucose meal was delayed in a distended gastric remnant in the patients with small stomach symptoms while the gastric remnant emptied rapidly

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of the distal part of the dural sac is sometimes not obtained with the patient prone owing to the curvature of the sacral canal Such a mechanical condition must also be recognized Subdural and epidural deposition of contrast medium may simulate complete spinal obstruction, the lateral view will usually afford the correct explanation (Fig 6, a and b)

Total obstruction to the flow of contrast medium was observed in films obtained at the beginning of the examination of certain cases not included in this series, as the examination proceeded, however, the flow continued in a caudal direction The obstruction was thus not complete Additional films, with an increase in the tilt of the table, should therefore always be obtained in cases of apparent obstruction

It must be stressed that the anaesthetic and contrast medium injected in cases of total obstruction may reach a higher level than would be expected under ordinary circumstances and cause collapse Complications may also occur in cases of partial obstruction, in which the medium may slowly reach distal regions that have not been anaesthetized, and lead to irritation of nerve roots, with severe pain

SUMMARY

Fourteen cases with complete obstruction of the spinal canal in a material of about 1 000 myelographies performed with a water soluble contrast medium together with 15 similar cases referred from elsewhere are considered and discussed An exact diagnosis was possible in most of the cases

ZUSAMMENFASSUNG

Aus einem Gesamtmaterial von 1 000 Fällen von Myelographien mit wasserlöslichem Kontrastmittel werden 14 Fälle mit Totalstopp des Wirbelkanals zusammen mit 15 ähnlichen überwiesenen Fällen besprochen Eine genaue Diagnosenstellung war meistens möglich

RÉSUMÉ

Les auteurs étudient 14 cas personnels d obstruction complète du canal rachidien provenant d environ un millier de myélographies faites avec un moyen de contraste hydro soluble et 15 autres cas semblables provenant d autres services Le diagnostic exact a été possible dans la plupart des cas

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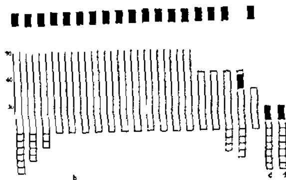


Fig 3 Group I No dumping symptoms White columns gastric emptying time black columns — small intestine transit time hatched columns — diffusion of fluid (slight moderate marked) Ordinate — time in minutes

in the contrast meal and following experiments of adding carbohydrate a mixture was evolved that appeared to fulfill the demands fairly well The mixture consisted of 55 g Redukal Leo or Suncomin Wallco 20 g sucrose 40 g Neobar and 200 ml water Redukal Leo contains 31 1 % protein 50 4 % carbohydrate 8 9 % lipid 5 6 % mineral and 4 % water The components were blended in an electric mixer the mixture was well emulsified and had a consistency of thin gruel and a calorie value of about 300

An investigation of stability and flocculation was performed by filling two aluminium cuvettes measuring 16 × 16 × 200 mm with a 20 % aqueous suspension of Neobar (a) and an aqueous suspension containing 20 % Neobar and 20 % Redukal (b) The cuvettes were placed where they would be undisturbed a film and a sheet of lead were put behind them and exposures made at 1/2 1 2 3 and 4 hours after they had been filled exposure factors 40 kV 900 mA FFD 4 m The experiment was repeated with the same concentration of Neobar (c) and Neobar + Redukal (d) suspended in gastric juice The addition of Redukal increased the sedimentation slightly (Fig 1) and the flocculation tendency increased especially in the uppermost layer where the lipids collect There was a considerable increase of sedimentation in the cuvette without Redukal after the addition of gastric juice (Fig 2) but no increase in the flocculation tendency was observed when Redukal+Neobar were suspended in gastric juice as compared with their suspension in water The somewhat greater flocculation caused by the addition of Redukal did not however prevent a satisfactory morphologic demonstration of the gastrointestinal tract

The normal series consisted of 25 males and females of ages ranging from 27 to 78 years None of them had had dyspepsia Films of the abdomen erect were obtained 1 20 45 and 90 minutes after the intake of the special meal, exposures were made at one hour intervals until the meal had reached the caecum The patient sat on a chair or walked about between the exposures The stomach was considered empty when a fluid level could no longer be

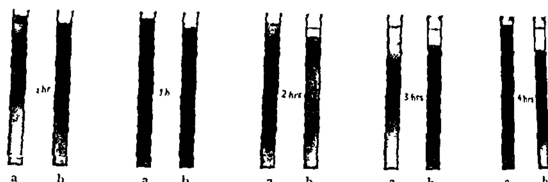


Fig 1 a) 20 % Neobar suspension at 1/2 1 2 3 and 4 hours after filling cuvette b) 20 % Neobar + 20 % *Redukal suspension at 1/2 1 2 3 and 4 hours after filling cuvette*

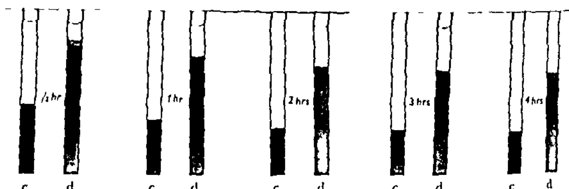


Fig 2 c) 20 % Neobar suspended in gastric juice at 1/2 1 2 3 and 4 hours after filling cuvette d) 20 % Neobar + Redukal suspended in gastric juice at 1/2 1 2 3 and 4 hours after filling cuvette

and diffuse clouding of the abdomen occurred in the 'dumpers', the meal *rapidly passed into the colon in the patient with postcibal diarrhoea* The method was not tried in a normal series MATTSSON et coll (1960) used a *physiologic contrast meal containing fat, protein, and carbohydrate* The gastric emptying was not accelerated but the meal had reached the caecum *by 15 to 30 minutes in 12 patients with dumping symptoms* ABBOTT et coll (1960) employed a contrast meal that contained milk, sugar, ice cream, and protenum The gastric remnant had no reservoir capacity and accelerated transit through the intestine occurred in dumpers Considerable clinical improvement was obtained after reoperation (narrowing the stoma, transforming Billroth II into Billroth I) and the gastric remnant was then found to act as a reservoir

A contrast meal containing food must be a homogeneous and stable suspension with little flocculation tendency, it should preferably also be easy to prepare and relatively palatable It must not induce false stimuli and, in particular, must not over stimulate the intestinal function but be as similar as possible to a normal meal After the introduction of reducing diets in powder form it occurred to the writers that these preparations migth be used as foods

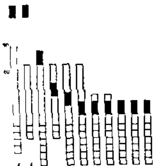


Fig 5 Group III Manifest dumping symptoms

Results

Figs 3, 4, and 5 present the gastric emptying time the transit time through the small intestine, and the degree of fluid diffusion The patients were followed for 90 minutes It may be said in general that patients without dumping symptoms had gastric emptying and small bowel transit times within the normal range and they seldom showed signs of fluid diffusion The gastric emptying as well as the transit through the small intestine were accelerated and there were signs of considerable diffusion of fluid into the bowel in the patients of group III About half the patients of group II had accelerated gastric emptying and signs of fluid diffusion into the intestine while the transit through the small bowel was on the whole normal Symptoms of dumping occurred in 6 patients (one of group II and 5 of group III) during the investigation

Five patients were examined twice Two had no dumping symptoms at the time of the first study but at follow up 6 months later both mentioned latent dumping symptoms and the roentgenologic appearances were altered — (a) in groups I and II (b) in groups I and II The third patient complained of latent dumping symptoms on both occasions and the roentgenologic appearances were identical — (c) in group II The fourth patient a 63 year old man who had undergone operation for gastric carcinoma (gastric resection with gastro oesophagostomy), presented evidence of a definite divergence between the clinical and roentgenologic findings — (d) in group I

There was no clinical suggestion of dumping and a provocation test with 150 ml of 50 % glucose failed to elicit any symptoms The gastric remnant emptied very rapidly and the transit through the small intestine was greatly accelerated The mucosal pattern in the terminal ileum was blurred and the caecum was distended with fluid The transit through the small bowel may possibly have been so greatly accelerated that only a small amount of fluid could be absorbed Fluid is rapidly absorbed in the caecum and ascending colon so that there was probably only moderate and short lasting exchanges of fluid between the intra and extracellular water phase on the one hand and the intestinal water phase on the other Amdrup (1960) has pointed out that patients who have undergone partial gastrectomy and have postcibal diarrhoea need not necessarily have dumping symptoms of any degree The cause he states is a rapid small intestinal transit so that only a small amount of fluid can diffuse into the small bowel there will consequently be only a slight fall in the plasma volume

The fifth patient was a man of 38 with advanced and typical dumping symptoms His general condition was satisfactory and he was not anaemic

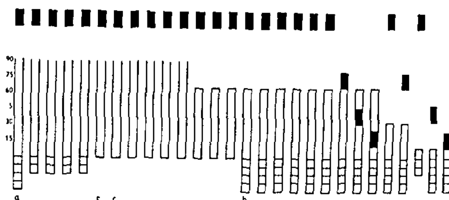


Fig. 4. Group II. Latent dumping symptom.

discerned. The emptying and the small intestinal transit times in normal subjects were as follows:

	Mean	Range
Gastric emptying time	140 min	90 (5 pts)—240 (1 pt.) min
Small intestinal transit time	180 min	90 (2 pts)—240 (8 pts) min

One patient had a gastric emptying and small intestinal transit time of 90 minutes, with signs of diffusion of fluid into the bowel shown by a blurred mucosal pattern and small fluid levels, none of the other normal subjects presented evidence of fluid diffusion.

The pathologic series comprises 55 patients in whom 60 examinations were performed. Forty five of these had been operated upon for benign and 10 for malignant gastric conditions, the surgical notes recording a Billroth I or Billroth II procedure in 50 patients, total gastrectomy with interposition of the jejunum in 2, subtotal gastrectomy with interposition of the jejunum in 1, and gastric resection with gastro oesophagostomy in 2 patients.

The patients were first encouraged to describe their condition and it was found that although they first said to have had no symptoms, a history of symptoms was often elicited by cautious questioning as to their diet. The patients on the basis of this dietary history were divided into three groups:

group I: those with no symptoms referable to meals — a total of 21 investigations,

group II: those with latent dumping symptoms, these could avoid symptoms by attention to their diet — a total of 28 investigations,

group III: those with manifest dumping, these were unable to avoid frequent or constant dumping symptoms in spite of a rigid diet — a total of 11 investigations.

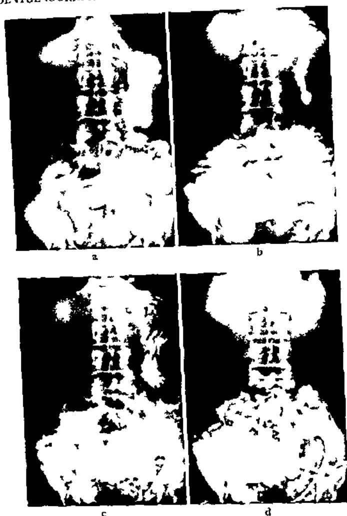


Fig 7 Patient with manifest dumping symptoms at 1 (a) 20 (b) 45 (c) and 90 min (d) p c respectively

It is well known that the most severe dumping symptoms are encountered in patients in whom an operation or histologic examination has failed to demonstrate a definite ulcer According to AMDRUP (1960) these patients may be suffering from the condition described by PORGES (1947) and believed to affect the small intestine dumping like symptoms and a rapid transit through the small bowel are part of the syndrome The writers are at present trying to ascertain whether preoperative investigations with a physiologic contrast medium can disclose an abnormal small intestine pattern in patients who develop severe dumping symptoms following operation

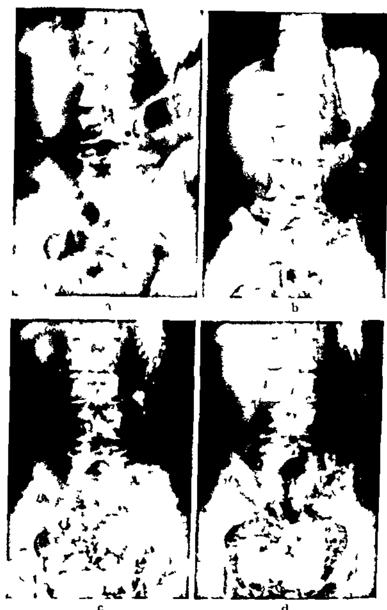


Fig 6 Patient without dumping symptoms at 1 (a) 20 (b) 45 (c) and 90 min (d) p c respectively

The gastric emptying and small intestine transit times were normal but there was moderate diffusion of fluid His symptoms were unchanged six months later, and he had lost weight, the gastric emptying was slightly accelerated, but the transit time through the small bowel was unchanged and there was only little diffusion of fluid into the gut — (f) in group III

Marked diffusion of fluid but a normal gastric emptying and a normal small intestine transit time were observed in a 56 year old man without dumping symptoms Exploratory laparotomy revealed carcinoma of the pancreas — (e) in group I

FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR PROF OLLE OLSSON) AND THE GYNAECOLOGIC DEPARTMENT OF THE RADIOTHERAPEUTIC CLINIC (DIRECTOR G GORTON) UNIVERSITY HOSPITAL OF LUND SWEDEN

LYMPHOGRAPHY IN THE DIAGNOSIS OF METASTASES WITH SPECIAL REFERENCE TO THE CARCINOMA OF THE UTERINE CERVIX

by

W A FUCHS and G BOOK HEDERSTROM

The principal value of lymphography lies in the ability to demonstrate early metastases in the pelvic and retroperitoneal lymph nodes Lymph node involvement in cases of advanced carcinoma may be apparent clinically and may be verified by indirect methods such as urography aortography pelvic phlebography and cavography, although early and minimal metastatic spread to pelvic and lumbar lymph nodes cannot be detected by these methods The diagnosis of a malignant lymphoma in these areas is valuable but not of utmost importance because this is a primary malignant tumor of the lymphatic system

Sixty cases of carcinoma of the uterine cervix were examined with a view to judging the value of lymphography in demonstrating early metastatic spread to lymph nodes This group represents the major part of our series of 101 cases of malignant disease examined by lymphography The report is limited to findings in cases of carcinoma of the uterine cervix

A preliminary report on the results were given in an earlier paper (FUCHS & BOOK HEDERSTROM 1961) and technical problems as well as the normal

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SUMMARY

A method of assessing the function of the gastrointestinal tract with a special contrast meal is described. The average gastric emptying and small bowel transit times in patients who had had partial gastrectomy but who were without dumping symptoms were within the normal range. Both were markedly accelerated and there was evidence of considerable fluid diffusion into the small bowel in patients with manifest dumping.

ZUSAMMENFASSUNG

Eine Methode zur Funktionsprüfung des Magen-Darmkanals mit einer besonderen Kontrastmahlzeit wird angegeben. Es zeigte sich, dass Patienten, die eine partielle Gastrektomie ohne dumping-Erscheinungen hatten, eine durschschnittlich normale Durchgangszeit des Darmes aufwiesen. Patienten mit dumping-Symptomen zeigten auffällige Beschleunigungszeiten und erhöhte Flüssigkeitsanreicherung im Dünndarm.

RÉSUMÉ

Les auteurs décrivent une méthode d'étude de la fonction gastrique et intestinale au moyen d'un repas opaque spécial. La durée moyenne de l'évacuation gastrique et du transit de *l'intestin grêle des malades qui ont subi une gastrectomie partielle, mais n'ont pas de dumping* syndrome est dans les limites normales. Mais chez les malades qui ont un dumping syndrome net, les deux sont notablement accélérés et le grêle contient une quantité considérable de liquide.

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Fig 1 Normal pelvic lymph nodes of different shapes with small rounded filling defects due to fibrotic area (pathologic verification) a) and c) Early filling stages b) and d) late filling stages (c) and (d) are of the same lymph node (oily contrast medium)

number and position as well as of the normal appearances of the nodes in these areas is encountered The same observation applies to nodes in the lumbar region

Normal pelvic and lumbar lymph nodes are round oval or bean shaped with a slight indentation in the hilum (Fig 1) The nodes vary in size, and measure up to 2 cm in diameter single lumbar lymph nodes may be up to 4 cm in length but their breadth never exceeds 1 5 cm (Figs 3 and 4) Contrast medium enters the nodes through numerous afferent lymphatics that join the lymph sinus at the periphery of the lymph nodes flows through the medullary lymph sinuses in streaks and leaves the lymph nodes by efferent lymphatics at the hilum (Fig 1 a and c) Contrast filling of lymph nodes is thus achieved centripetally from the peripheral sinus towards the hilum The peripheral sinus of the nodes is often homogenously filled (Fig 2a) but small rounded filling defects may be observed under normal conditions (Fig 1 a and b) Rounded filling defects of various sizes are also often encountered in the central parts of normal lymph nodes and their distribution may or may not be uniform (Figs



Fig 2 Normal pelvic lymph nodes a) Homogeneously filled peripheral sinus central filling defects due to fibrotic area (pathologic verification) b) Large lymph nodes with large rounded filling defects due to fibrotic area (pathologic verification) (water-soluble contrast medium)

Table

Material of carcinoma of the uterine cervix

	Number of cases	Number of lymphographies	Correct diagnosis proven by		Overdiagnosis proven by		Correct diagnosis missed but proved by	
			Microscopic examination	Clinical course	Microscopic examination	Clinical course	Pathology	Clinical course
Stage I	19	28	12	15	1	—	—	—
Stage II	29	48	22	20	2	1	1	2
Stage III	11	16	3	6	—	—	—	7
Stage IV	1	2	—	2	—	—	—	—
Total	60	94	37	43	3	1	1	9
			80		14			

topographic roentgen anatomy of the lymphatic system in the inguinal and pelvic region were described. The investigation technique and anatomy will therefore not be described again in detail.

Material. Lymphography was performed bilaterally in 34 of 60 cases of carcinoma of the uterine cervix, 26 cases were examined only on the side on which malignant involvement was probable clinically. The total number of lymphographies performed was therefore 94, all of which were technically adequate for diagnosis (see Table).

Cases of carcinoma of the uterine cervix were chosen because the pelvic and lower lumbar lymph nodes, where metastatic spread of this type of carcinoma can be expected, are well demonstrated by the present technique of lymphography. Furthermore, extraperitoneal lymph node excision (GORTON 1953, 1957) ensured histologic control of the roentgenographic findings. The roentgenologic diagnosis in 41 lymphographies was controlled by lymph node excision and in the remaining 53 investigations the findings were compared and evaluated with the clinical course of the condition (see Table). As the purpose of the investigation was to detect early lymph node involvement most of the cases belonged to stages I and II. Cases of advanced carcinoma were also examined in order to obtain a clear picture of the typical pathologic changes.

Seventy seven lymphographies were performed with water soluble contrast media, and in 17 lymphographies oily contrast media (5 ml to 10 ml), in cases only in which the former failed to furnish conclusive results.

Normal lymph node anatomy. The basic topographic anatomy of lymph vessels and lymph nodes in the inguinal and pelvic region accessible by the present technique of lymphography is constant, although considerable variation in the

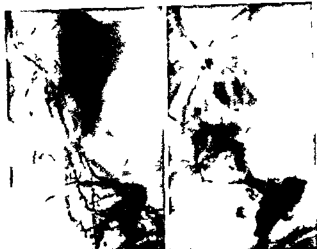


Fig 4 Normal pelvic lymphography in a case of carcinoma of the uterine cervix stage II before radiation treatment (pathologic verification) *Left* Early stage of the investigation The oily contrast medium passes directly from the afferent to the efferent lymphatics without demonstrating the lymph node *Right* 24 hours later The nodes with their physiologic filling defects are demonstrated



Fig 5 Normal pelvic lymphogram in a case of stage II carcinoma of the uterine cervix, 6 months after radiation treatment (pathologic verification) (oily contrast medium)

The roentgenographic structure of the lymphatic system before during and 2 to 3 months after radiation therapy of carcinoma of the uterine cervix presented no marked variation Irradiated lymph nodes seemed to be somewhat smaller in some cases although the lymphatics showed no abnormal changes or were finer than normal (Fig 5)

Water soluble and oily contrast media often pass in the first stage of the investigation directly from the afferent lymphatics through a few medullary lymph sinuses to the efferent lymph vessels of a lymph node without demonstrating the parenchyma of the lymph node as a whole (Fig 4) Water soluble contrast media diffuse through the parenchyma during the further course of the investigation and in late stages may obscure small filling defects Serial roentgenograms must therefore be taken during the whole course of the contrast injection No such diffusion is encountered with oily contrast media and filling defects in lymph nodes stand out clearly in roentgenograms obtained immediately after the injection (Fig 1, a and c)

There is however the possibility that filling defects may be obscured by an excessive amount of contrast medium or by contrast filled lymph vessels situated close to the lymph nodes (Fig 3a) Twenty four hours after injection the contrast medium has passed largely from the lymph vessels into he lymph nodes and the physiologic filling defects are then more marked particularly in the region of the hilum and in the peripheral lymph sinus (Figs 1b, 3b, 4b) This phenomenon is due to the fact that the continuous lymph flow carries



Fig 3 Normal pelvic lymphogram in a case of carcinoma of the uterine cervix stage I before radiation treatment a) Nodes obscured by filled lymph vessels in roentgenogram taken immediately after injection of oily contrast medium b) 24 hours later only the nodes with their physiologic filling defects are demonstrated

1 and 2) These latter filling defects are due to areas of fibrotic degeneration that do not take up contrast medium, such changes were confirmed histologically in all inguinal and pelvic lymph nodes without malignant involvement and may therefore be considered as a normal physiologic involution of the lymphatic system The central parts of these lymph nodes may be totally replaced by fibrosis so that lymphatic tissue is left only in the periphery of the nodes (Fuchs et coll 1960)

No considerable variation in the lymphographic pattern in different age groups was observed The lymphatic system was somewhat better developed and the lymphatics were broader in the younger groups but the nodes were more numerous than in the older groups (Figs 3 and 4) In addition, 'physiologic filling defects due to fibrotic involution were thought to be more marked in the latter The youngest subject investigated was of age 28 the oldest 68 years

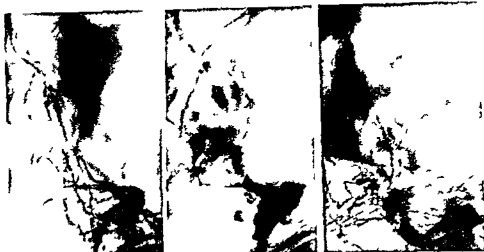


Fig 4 Normal pel c lymphography in a case of carcinoma of th uterine cervix stage II befo e radiation treatment (patholog c ver f cat on) *Left* Early stage of the investigation Th o ly con trast medium passes d rectly from the afferent to the efferent lymphatics without demonstrat ng the lymph node *R ght* 24 hours l ter The nodes with the phys olog c fill g d fects are d mon str t d

F g 5 Normal pel c lymphogram in a case of stag II carcinoma of the uterine cervix 6 months after radiation treatment (patholog c verificat on) (o ly contrast me d um)

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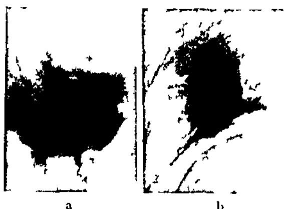


Fig. 6. Enlarged metastatic pelvic lymph nodes with regular contours and rounded central filling defects (water soluble contrast medium). a) Case of carcinoma of the uterine cervix stage III (pathologic verification). b) Another case of carcinoma of the uterine cervix, stage III (indicated by the rapid and fatal course).



Fig. 7. Enlarged metastatic pelvic lymph nodes with peripheral and central filling defects (water soluble contrast medium). a) Case of carcinoma of the uterine cervix, stage IV (indicated by the rapid and fatal course). b) Case of carcinoma of the uterine cervix stage II (pathologic verification).

away the contrast medium which is not phagocytized by macrophages of the lymph nodes or retained within the meshwork of the lymph sinuses.

Diagnosis of malignant pathologic changes

A correct diagnosis of tumor involvement was made in 14 of our series of 94 lymphographies performed in 60 cases of carcinoma of the uterine cervix. Six of these findings were verified by extraperitoneal lymph node excision, and 8 were proved by the subsequent fatal termination. One lymphography was diagnosed as normal, whereas malignant changes were found at operation. On the other hand, malignant involvement of lymph nodes was diagnosed in 3 cases in which only chronic inflammatory changes were evident at operation. Nine lymphographies in clinically advanced cases of malignant involvement showed no pathologic changes. On five occasions, metastatic malignancy in lymph nodes was diagnosed by lymphography, in the absence of positive clinical findings, and operation revealed the lymphographic diagnosis to be correct.

To summarize, in a total of 94 lymphographies the roentgenologic diagnosis was correct in 80 and was misleading or wrong in 14. The latter included cases of early malignant involvement, as well as cases with clinically advanced malignant disease but without pathologic changes on lymphography. A survey of these figures is given in the Table, p. 162.

The following lymphographic changes were found in the presence of malignant metastatic spread:

1. Enlarged lymph nodes with regular peripheral contours and rounded central filling defects (present in 3 lymphograms) (Fig. 6).



Fig 8 Normal sized metastatic pelvic lymph nodes with irregular contours due to tumor infiltration in the peripheral lymph sinus a) Case of carcinoma of the uterine cervix stage III (pathologic verification) (water soluble contrast medium) b) Another case of carcinoma of the uterine cervix stage III (pathologic verification) (oily contrast medium)

2 Enlarged nodes with filling defects in the peripheral lymph sinus and in the central parts of the nodes (found in 3 lymphograms) (Fig 7)

3 Normal sized nodes with irregular contours caused by filling defects in the peripheral lymph sinus due to tumor infiltration (seen in two investigations) (Fig 8)

4 Total infiltration of nodes by malignant invasions obstruction of their afferent lymphatics and the formation of collateral circulation to neighbouring groups of lymphatics and even to the contralateral side (Fig 9)

Considerable narrowing of the afferent lymphatics close to the pathologic area was often present this change was encountered in six investigations and was mainly evident in cases of advanced malignant disease

Discussion

Certain important questions on the actual value of lymphography in the diagnosis of metastases based on observations made in this series of investigations will be considered

Experimental lymphographic studies by Tjernberg (1956 1959) revealed metastatic lymph nodes as enlarged structures with rounded and irregular filling defects corresponding to the malignant growth Fischer & Zimmermann (1959) in animal experiments simulated metastases in lymph nodes by embedding polythene balls surgically these were demonstrated as small negative filling defects at lymphography These authors as well as Malek et coll (1959) also showed however that filling defects were not pathognomonic of malignant disease as they could also be caused by experimentally produced small abscesses in lymph nodes

Several authors (Wallace et coll 1961, Mollonguet Doleris et coll 1961, Ruttimann et coll 1961 Marchal et coll 1961 Kritter et coll 1962) considered normal and chronic inflammatory lymph nodes to have a homogenous reticular pattern Furthermore they have indicated that the nodes are best demonstrated by oily contrast media in roentgen films obtained 24 hours after injection



Fig. 9. Total obstruction of the superficial lateral external iliac group of lymphatics with collateral circulation through the medial external iliac lymphatics to the contralateral side. Case of carcinoma of the uterine cervix, stage II (verified at operation) (oily contrast medium).

Our present study revealed variously sized filling defects in the central as well as in the peripheral parts of pelvic and lumbar lymph nodes not affected by malignant disease; the defects cannot therefore be accepted as absolute evidence of malignant metastatic involvement, an opinion that is shared by SHEEHAN et coll. (1961) and FISCHER et coll. (1962). Because the defects are most prominent in roentgen films obtained 24 hours after injection, evaluation of these films together with those obtained immediately after the injection is of importance; the lymph vessels are demonstrable only in the latter and the presence of a collateral circulation and of pathologic changes in lymphatics afferent to the tumor area will be recognized only at this stage of the investigation.

Enlargement of a lymph node does not necessarily signify the presence of metastases since normal and chronically inflammed nodes may vary in size and those invaded by a neoplasm need not necessarily be enlarged Considerable lymph node enlargement, with the presence of extensive irregular filling defects will indicate metastatic involvement Such appearances are, however encountered mainly when clinical signs of malignancy are evident

Minute filling defects due to malignant infiltration cannot be shown by lymphography GOFFRINI et coll (1961), in their roentgen micrographic studies in which they compared lymphographic findings with the corresponding histologic investigations, found that small neoplastic infiltrations cannot be identified even by microangiography Since the resolving power of the ordinary lymphographic technique is significantly lower than microangiography neoplastic involvement in lymph nodes cannot be recognized until it has significantly progressed

Although the basic anatomical pattern of inguinal and pelvic lymph nodes may be constant the number of such nodes that are filled with contrast medium may vary considerably Failure to demonstrate one lymph node or a whole group of nodes cannot be taken as evidence of malignant infiltration The differentiation of an anomaly from complete obstruction of a lymphatic chain due to involvement with a consequent collateral circulation may be made from the absence of pathologic lymph vessels and by noting the presence of any anatomical variation Displacement of lymph nodes and lymph vessels is of limited value as a diagnostic sign of malignant involvement of the neighbouring area due to the anatomical variation of the lymphatic system In none of the cases was the diagnosis of infiltration based upon these grounds

The more medially situated pelvic lymph nodes are not demonstrated by the present technique of lymphography as mentioned in our preliminary report These medial nodes are usually involved earlier than the lateral nodes in metastatic spread from carcinoma of the uterine cervix, and normal pelvic lymphography does not therefore exclude metastases in more medially situated lymph nodes Malignant involvement of these nodes may on the other hand be diagnosed better clinically than in the more laterally localized nodes Distant metastases may occur before nodes in close proximity to the primary tumor are involved and this increased the possibility of detecting early malignancy in lymph nodes by lymphography This fact applies not only to carcinoma of the uterine cervix but to malignant tumors of other pelvic organs as well Exact knowledge of the topographic anatomy of the regional lymph nodes of organs in which metastatic spread may be expected is therefore of the utmost importance

Conclusions

The investigation leads to the conclusion that the diagnostic value of the method is limited especially when the early detection of metastatic spread to

lymph nodes has to be made. The high expectations expressed by several authors (COLLETTE 1958, 1959, WALLACE et coll. 1961, MOULONGUET DOLERIS et coll. 1961, RUTTIMANN et coll. 1961, KRITTER et coll. 1962) seem to be fulfilled only to a limited extent. In our series, the rate of error was approximately 15 %, and the danger of an erroneous diagnosis was particularly real when clinical signs of lymph node involvement were absent.

It would appear to the writers that a diagnosis of metastases in lymph nodes may be made with certainty in the presence of complete obstruction of a lymphatic chain with a collateral circulation, and when enlarged nodes with extensive peripheral filling defects are demonstrated.

Early metastatic involvement of lymph nodes is, however, difficult to detect. The relatively low resolving power of the macroscopic method of lymphography, the great variation in lymph nodes with their physiologic filling defects, and the failure to demonstrate medially localized pelvic lymph nodes, which are often first involved, leads to a considerable diagnostic limitation of the present technique of lymphography. The danger of arriving too readily at positive conclusions as well as of overlooking small pathologic changes is apparent. An accurate lymphographic diagnosis of malignant metastases can often only be made when the clinical findings are already obvious and indirect roentgen methods have demonstrated the condition. In some cases, however, malignant spread to pelvic lymph nodes is shown by lymphography when clinical signs are absent or only probable.

Although lymphography is more time consuming than more conventional methods, such as urography, pelvic phlebography, and cavography, the important fact remains that direct diagnostic approaches are undoubtedly superior to indirect ones.

Further experience will certainly lead to a more exact knowledge of the lymphographic pattern in early malignant metastatic spread. The diagnosis of minute lesions may perhaps become possible in the future although it is not to be expected that microscopic changes in lymph nodes will ever be demonstrated by the macroscopic method of lymphography.

SUMMARY

The diagnostic possibilities and limitations of lymphography in the demonstration of malignant metastatic spread in lymph nodes are discussed. Metastases in lymph nodes which cannot be detected clinically and by conventional roentgen investigations may be demonstrated by lymphography in certain cases.

ZUSAMMENFASSUNG

Die diagnostischen Möglichkeiten und Grenzen der Lymphographie zur Darstellung von Krebsmetastasen in Lymphknoten werden diskutiert. Lymphknotenmetastasen die klinisch und mit den konventionellen Röntgenuntersuchungsmethoden nicht erfasst werden können in gewissen Fällen durch die Lymphographie diagnostiziert werden.

RÉSUMÉ

Les auteurs étudient les possibilités diagnostiques et les limites de la lymphographie pour le diagnostic des métastases ganglionnaires malignes La lymphographie permet de mettre en évidence des métastases ganglionnaires dans des cas ou la clinique et les examens radiologiques habituels s averent impuissants

Addition in proofs

Since the article was submitted the results presented have been confirmed

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR R E FISCHEL) KAPLAN HOSPITAL,
REHOVOT, ISRAEL

HERNIATION OF A STONE-FILLED GALLBLADDER THROUGH THE DIAPHRAGM

by

R E FISCHEL and E M JOEL

It is well known that nearly all the abdominal organs may herniate through the diaphragm Herniation of the stomach, colon, omentum or small intestines is fairly common but herniation of the spleen, pancreas or kidneys is rare and no case of herniation of the gallbladder through the diaphragm would appear to have been reported

Case report

Woman aged 58 with 6 months history of severe colicky pain in the right hypochondrium The attacks lasted a few days and recurred several times usually following fried or fatty food they were not accompanied by jaundice or fever Routine roentgen examination of the chest a year previsously had revealed no abnormality

At roentgen examination of the stomach and colon the findings were normal At chole cystography no evidence of gallbladder function

Cholegraphy The gallbladder was again not filled and the hepatic ducts were not demon strated Films of the chest disclosed a rounded apple sized soft tissue mass in the right anterior basal zone This changed in character from one examination to another at times appearing demarcated and apparenty encapsulated (Fig 1) The mass was in fact the gallbladder (Fig 1b) Furthermore it was filled with stones (Fig 2a) The common bile duct was not obviously abnormal but the cystic duct was stretched Contraction of the gallbladder after a fatty meal proceeded normally

Submitted for publication 10 September 1962



Fig. 1. a) A rounded well-defined soft tissue mass adjacent to the mediastinum with the crescent of a thin capsule beyond it. b) Lateral view. The rounded mass lies in the right cardiophrenic angle.

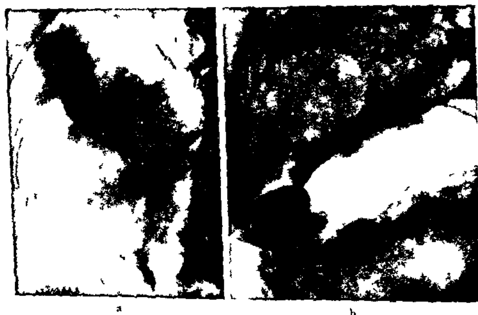


Fig. 2. Intravenous cholegraphy. Multiple calculi in an abnormally situated gallbladder. b) Pneumoperitoneum. Gas-filled sac (arrows) in anterior part of thorax and below it the filled gallbladder.



Fig 3 Right lateral decubitus and prone positions The stone filled gallbladder (after cholegraphy and pneumoperitoneum) within the diaphragmatic hernial sac

A pneumoperitoneum was performed in order to decide whether the gallbladder lay in a bulge of a normal diaphragm or passed through an aperture i e in a hernial sac Following the simultaneous injection of 1 000 ml CO_2 into the peritoneal cavity during cholegraphy the spleen and liver as well as both cupolas of the diaphragm were well seen A gap about 3 cm wide through which the gas passed into a sac of the shape and size of the gallbladder was evident in the anterior portion of the diaphragm behind the sternum to the right of the mid line (Fig 2b) By changing the position of the patient it was possible to move the gallbladder from the hernial sac in the left lateral decubitus and erect postures and return it to the hernial sac in the right lateral decubitus Trendelenburg and prone positions (Fig 3)

Operation The abdomen was explored through a right subcostal incision The gallbladder was rotated on its axis with its fundus located in an aperture about 5 cm long and 1 cm wide between the cartilages of the 6th and 7th ribs and the diaphragm on the right side The gall bladder was delivered from this opening into the abdominal cavity a mesentery 2 cm wide and 4 cm long that was attached to its neck and proximal part leaving the distal part free and mobile The cavity in the chest was covered by subperitoneal fat continuous on the medial aspect with the fat of the ligamentum teres and was lined by a serous membrane This sac extended into the anterior mediastinum and could be easily returned to the abdominal cavity The sac was excised at its neck and the gap was closed The left lobe of the liver was unusually small and mobile The cystic artery and duct were identified ligatured and cut and the gall bladder was then removed

The recovery of the patient was uneventful

Discussion

According to FELDMANN (1958) the incidence of protrusion of an abdominal viscus into the thoracic cavity through a congenital diaphragmatic defect is 0 07 per cent In the majority of these cases the hernia is situated in the pos

terior portion of the left diaphragm the liver rendering the right side less liable to herniation These case are generally fatal in infancy unless operated upon in time They may however, remain occasionally symptomless until later in life KIRKLAND (1959) found that in the period between 1853 and 1959 only 34 cases of adult posterolateral congenital diaphragmatic hernia were published

On the other hand, in retrosternal or anterior diaphragmatic or subcostosternal diaphragmatic hernias, so-called herniation through the foramen of Morgagni it would appear that symptoms of any kind even minor ones, seldom occur during infancy or childhood Many cases probably remain symptomless throughout life The main reason for this seems to be the fact that in posterolateral defects free communication between the pleural and peritoneal cavities exists whereas in retrosternal herniation the peritoneal cavity becomes sealed from the pleural cavity by a peritoneal sac *Five cases all on the right side and in women*, 4 of them over 60 years of age were reported in HUNTER s excellent review (1959) of hernias through the foramen of Morgagni The hernia in the present case was on the right side and the patient first complained of symptoms in her 59th year It should be noted however, that the hernia was apparently symptomless and was an incidental finding as the symptoms were referable to a normally placed gallbladder

McCREA *(1951) reported* a case of herniation of the gallbladder through the foramen of Winslow into the lesser omental sac A few cases are recorded of a *subcutaneous* gallbladder containing stones and presenting a painless mass in the right upper abdominal quadrant A gallbladder has also been found in an *inguinal hernial sac* The present case appears to be the only *one encountered* of herniation of the gallbladder through the foramen of Morgagni

Acknowledgement

Our thanks are due to S Teva Director of the Surgical Department who performed the operation and supplied *the details of the* operation

SUMMARY

A case of herniation *of a stone filled gallbladder* through the diaphragm diagnosed by intravenous cholegraphy and *pneumoperitoneum* and confirmed at operation is described

ZUSAMMENFASSUNG

Ein Fall von Zwerchfellbruch mit einer Gallenblase voll von Steinen wurde mittels intravenöser Cholecystographie kombiniert mit *Pneumoperitoneum* diagnostiziert

RÉSUMÉ

Présentation d un cas de *hernie* diaphragmatique d une vésicule biliaire remplie de *calculs* diagnostiqué par cholégraphie intraveineuse et pneumopéritoine et vérifié à l opération



Fig 3 Right lateral decubitus and prone positions The stone filled gallbladder (after cholegraphy and pneumoperitoneum) within the diaphragmatic hernial sac

A pneumoperitoneum was performed in order to decide whether the gallbladder lay in a bulge of a normal diaphragm or passed through an aperture i e in a hernial sac Following the simultaneous injection of 1 000 ml CO_2 into the peritoneal cavity during cholegraphy the spleen and liver as well as both cupolas of the diaphragm were well seen A gap about 3 cm wide through which the gas passed into a sac of the shape and size of the gallbladder was evident in the anterior portion of the diaphragm behind the sternum to the right of the mid line (Fig 2b) By changing the position of the patient it was possible to move the gallbladder from the hernial sac in the left lateral decubitus and erect postures and return it to the hernial sac in the right lateral decubitus Trendelenburg and prone positions (Fig 3)

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MUSCULAR SUBVALVULAR AORTIC STENOSIS

Abnormal anterior mitral leaflet possibly the primary factor

by

P FRIX A MOBERG, H SODERBERG and J KARNELL

Subvalvular aortic stenosis may be of two types The first which has long been recognized is characterized by a fibrous ring situated about 1 cm below the aortic cusps (GOULD) and in the majority of cases, is *in the nature* of a congenital malformation This type of subvalvular stenosis should be hemodynamically *identical with* valvular aortic stenosis The second type first described by BROCK (1957), TEARE (1958), BERCU et coll (1958) MORROW et coll (1959) BRACHFIELD et coll (1959) has frequently been referred to during the last four years The *condition* is characterized by a localized muscular bulk in the ventricular septum protruding into the outflow tract which is *thought* to cause the subvalvular stenosis Various names have been used for the condition such as functional aortic stenosis (MORROW & BRAUNWALD) asymmetric hypertrophy of the heart (HOLLMAN et coll) obstructive cardiomyopathy (GOODWIN et coll) and pseudoaortic stenosis (BERCU et coll)

Muscular subvalvular aortic stenosis is of great interest because (1) the pathology up to recently has hardly been recognized and the pathogenesis

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Table 2

	Number of cases	Case numbers
Dyspnoea at rest	3	9 10 12
on exertion	8	1 2 3 5 6 7 8 11
Precordial pain (on exertion)	5	2 3 5 7 9
Fatigue on exertion	5	1 2 3 7 8
Arrhythmia	6	3 7 8 9 10 12
Syncope	3	3 8 9
No symptoms	1	4

side by the JONSSON BRODEN & KARNELL method Only one catheter was used in the examination of the left side of the heart The pressure was first measured in the ascending aorta and then after a short interval in the left ventricle there was no simultaneous pressure registration from the aorta and the left ventricle by means of an extra aortic catheter The authors are aware that even slight variations in cardiac output may change a pressure gradient between the aorta and the left ventricle but despite this believe that it was possible to assess the pressure gradient during these investigations It is also worth studying the aortic pulse curve in relation to the pressure curve from the left ventricle, simultaneous registration would have been valuable for such an investigation The curves from the aorta and the left ventricle were however inscribed upon each other in corresponding periods of time, the ECG registered in all the curves being used as the base

Table 3

Case	Murmur	Blood pressure	Electrocardiography Rhythm	QRST
1	Systolic	130/70	Regular	Small LBBB
2	Systolic	125/80	Regular	LV strain
3	Systolic	120/80	Regular ES	LV strain
4	Systolic	130/70	Regular	LV strain
5	Systolic	135/80	Regular	Part RBBB
6	Systolic	120/80	Regular	Small LV strain
7	Systolic	135/80	Regular Parox fibr	Normal
8	Systolic	135/90	Regular Parox. fibr	LV strain
9	Systolic	130/80	AV block I II Total AV block	LV strain
10	Systolic	110/85	Parox. tachycardia	RV strain
11	Systolic	160/90	Regular	LV strain
12	Systolic	200/105	Fibrill	LV strain

LBBB RBBB left right bundle branch block LV RV strain = left right ventricular strain
ES extra systoles

Table 1

Case	Sex	Age at examination	Sympt since age of	Heart side catheterized L = left R = right	Site of contrast injection	Age at death	Remarks
1	m	28	childh	L + R	PA Asc Ao	30	
2	m	43	36	L + R	PA LV	43	Died post operatively
3	f	32	29	L + R	LV		
4	m	36	asympt	L + R	LV		
5	f	18	14	L + R	LV LV		
6	m	24	childh	L + R	LV LV		
7	m	51	25	L + R	PA LV		
8	m	43	40	L + R	LV		
9	f	42	30	incompl		42	
10	m	67	50			67	Died from noncardiac disease
11	m	43	25	incompl		43	
12	m	76	50–60			76	Died from noncardiac disease

remains obscure, (2) it is difficult to diagnose, (3) sudden death at an early age may occur, and (4) efforts to correct the condition surgically have hitherto not been very successful

The present authors have examined 12 cases of muscular subvalvular aortic stenosis and arrived at conclusions that may point to the pathogenesis and consequently be of value in the surgical treatment of the condition

Material

The material of 12 cases was investigated between 1953—1961 The sex, age at the first symptoms, and at examination, as well as the investigations performed, are shown in Table 1

Symptoms Since the symptoms are well recognized they are given in tabular form only (Table 2)

Signs The murmurs and blood pressure as well as the ECG changes are shown in Table 3

Catheterization Heart catheterization and angiocardiography were performed on the left side according to HANSSON, JONSSON & KARNELL and on the right

Table 2

		Number of cases	Case numbers
Dyspnoea	at rest	3	9 10 12
	on exertion	8	1 2 3 5 6 7 8 11
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7	Systolic	135/80	Regular	Normal
8	Systolic	135/90	Parox fibr Regular	LV strain
9	Systolic	130/80	Parox fibr AV block I II	LV strain
10	Systolic	110/85	Total AV block Parox tachycardia	RV strain
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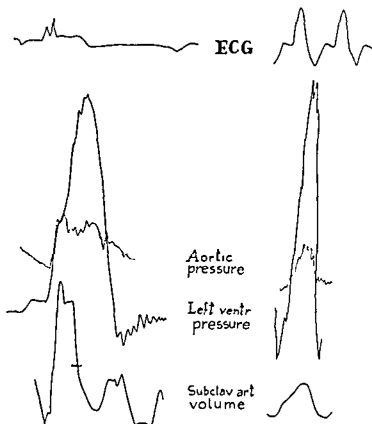


Fig 1 Pressure curves from the aorta and the left ventricle and a subclavian volume pulse curve in a case of muscular subvalvular aortic stenosis (left) Corresponding curves from a case of valvular aortic stenosis are given for comparison (right) The ECG is taken with a special lead during the catheterization to show only the beginning of systole

Results

Catheterization and angiocardiography were carried out in Cases 1 to 8, in Cases 9 and 11, catheterization was begun but was discontinued on account of serious arrhythmia that arose when the catheter passed the right ventricle One of these subjects died (Case 11) and the other, who survived, developed an Adam Stokes syncope following total heart block

The anatomical conditions in Cases 2, 5, 6, and 7 made it difficult to manipulate the catheter tip to the base of the left ventricle without risk, an angiocardiographic demonstration of the changes was, however, made even though a pressure gradient was not recorded A systolic pressure gradient of 40 to 117 mm Hg was registered in the other four cases

The following observations were made on the basis of the pressure curves from the aorta and the left ventricle in Cases 1, 3, 4, and 8 in which the catheter passed the stenosis and a gradient was recorded The curves were of identical

Table 4

Case	Card vol total cc/BSA m	LV syst/end diast mm Hg	Catheterization pressures AscAo syst/diast mm Hg	RV syst	PA syst	PCV mean
1	910 640	186/32	115/71	34	18	11
2	1 050 640	131/20	131/88	—	—	14
3	980/530	214/34	100/60	47	42	21
4	810/430	130/16	90/50	40	30	12
5	760 530	126/5	126/70	15	10	4
6	780 360	107/13	103/53	24	21	—
7	1 100/540	131/5	128/53	28	25	12
8	1 080/5 0	159 13	87/56	30	33	24
9	680 410					
10	1 050/700					
11	1 310 690					
12	enlarged					

shape in all the cases (Fig 1) An incisura was noted in the middle of the steeply ascending limb in the ventricular curve after which the curve continued to rise though less steeply The aortic curve ceased to ascend at the incisura and the aortic pressure then fell continuously down to the dicrotic incisura which marks the closure of the aortic cusps Maximum pressure was thus considerably earlier in the aortic than in the ventricular curve

A small pressure gradient was observed between the right ventricle and the pulmonary artery in at least three of the cases (Cases 1 5 and 7) in two of these (Cases 1 and 7) the curve registered was similar to the one described above although less prominent The gradient was small and probably without major hemodynamic significance

The PCV was on the upper normal limit in 3 cases and in 3 cases obviously abnormal it was normal in 1 case and in 1 case it was not registered An increased end diastolic pressure was registered in the left ventricle in the cases in which the PCV was increased The aortic pressure was normal in all cases (Table 4)

Volume pulse recording was performed in four cases Plethysmographic recordings from the fingers and toes in 2 cases (Cases 3 6) revealed no pathologic changes Subclavian pulse curves were recorded in 2 cases (Cases 3 8) in Case 8 the curve was technically unsuccessful and in Case 3 it was of an unusual type that was reproduced several times during an observation period of four years (Fig 1)

Roentgenology Conventional roentgenograms of the heart revealed enlargement of the left ventricle and left atrium in all cases No calcifications in the aortic valve area were visible nor was there any evidence of post stenotic dilatation of the ascending aorta



Fig. 2. Angiocardiographic and schematic appearances of muscular subvalvular aortic stenosis (lateral view), mid systole. MB = muscular bulk. AML stands immediately to the right of the line indicating the anterior mitral leaflet.

The anatomy of the left ventricle was studied by angiocardiography. The ventricular wall was generally thickened and the lateral wall varied between 13 and 20 mm. Both the papillary muscles and the trabeculae carneae were hypertrophic. The aortic cusps were normal and the coronary arteries were widened in all cases.

A varying stenosis was observed below the aortic cusps in the outflow tract which had the appearance of a cone, the base of which faced the aortic cusps. This stenosis was most marked 19.5 to 31 mm below the aortic ostium. The anterior part of the stenosis was formed by a thick bulk in the anterior septal part of the ventricular wall. This bulk protruded into the left ventricle and was thickest in late systole. The posterior part of the stenosis was formed by the anterior (aortic) mitral leaflet which protruded more than normally; a part of the leaflet produced a bulge into the outflow tract in ventricular systole. The apical part of the leaflet was less mobile than usual in most of the cases. The stenosis was most marked in late systole, but remained until the end of the diastolic phase (Figs. 2 and 3).

The anterior mitral leaflet seemed to be fixed more medially and anteriorly



Fig 3 Angiocardiographic and schematic appearances of muscular subvalvular aortic stenosis (lateral view) diastole MB — muscular bulk AML stands immediately to the right of the line indicating the anterior mitral leaflet

than normal in Cases 4 and 6 Regurgitation of contrast medium to an enlarged left atrium was noted in Cases 3 4, 6 and 8

The posterior part of the stenosis, i e the anterior mitral leaflet, was measured in the roentgenograms in all the cases These measurements were made from the lower edge of the orifice of the left coronary artery to the edge of the mitral leaflet reference points selected in order to obtain fixed measuring points Corrections for the bulging shape of the leaflet were not made This means that the measurements taken for the length of the anterior mitral leaflet were minimal The maximum and minimum widths of the stenoses and the length of the anterior mitral leaflet are given in Table 5 Similar measurements in a number of cases investigated for conditions not involving the mitral or aortic ostia (control cases) are given for comparison

Pathology Six subjects died A post mortem examination was not permitted in Case 2 but autopsies were carried out on Cases 1, 9 10 11 and 12 The heart presented similar changes with only minor detailed variations in all

Table 5

Cases	Width of stenosis in mm		Length of anterior mitral leaflet in mm
	Min	Max	
1	9 5	23 0	47
2	11 0	15 5	43
3	5 5	15 5	33
4	6 2	19 5	31
5	5 5	17 2	31
6	22 0	31 0	47
7	15 5	27 0	35
8	11 0	22 0	43
Mean values	10 8	21 3	39
Mean value of control cases			24

All values are corrected for geometrical distortion caused by divergence of the roentgen rays

cases Marked hypertrophy of the left ventricle and dilatation of the left atrium were observed but the right ventricle was not involved in any of the cases The aortic cusps were normal or only slightly atheromatous A large muscular bulk protruded into the left ventricle some 1 5 to 2 cm below the aortic cusps At its thickest part this bulk was about 3 cm, while the myocardium of the left ventricle was generally less than 2 cm in thickness The bulk was localized to the ventricular septum, and in the transverse section was almost triangular in shape Cases 1, 9, 10, and 11 had changes in the anterior mitral leaflet, the leaflet was thickened in Cases 1, 9, and 11, and in Cases 1 and 9 the chordae tendineae were also slightly thickened (Fig 4) The posterior mitral leaflet was slightly thickened in Case 1 but unchanged in the other cases There was no adhesion between the leaflets, and the mitral ostium was of normal width The medial part of the anterior mitral leaflet had fused with the ventricular septum in Case 10 and as a result of this the leaflet was displaced medially The measurements and weights of the hearts in the individual cases are given in Table 6

The length of the anterior mitral leaflet was measured in two of the cases by taking the distance between the root of the leaflet at the annulus fibrosus and its edge (leaflet length) The length of the chorda tendinae from the edge of the leaflet to the anterior papillary muscle was also measured (chorda length) Since no information on the length of the normal mitral leaflet was found in the available literature control measurements were carried out on a series of thirty subjects who had died from other causes (control cases) These latter measurements were taken at the post mortem examination while the hearts of the two subvalvular cases were fixed in formalin Material fixed in formalin has a tendency to shrink and it is thus possible that the measurements in the subvalvular cases were less than they would have been if measured during the post mortem examination The weight of the heart in the control



Fig 4 Muscular subvalvular aortic stenosis The myocardium is considerably thicker in the septal area than at the apex Thickened anterior mitral leaflet and chordae tendineae The thickened endocardium over the muscle bulk is probably caused by increased pressure from the blood stream

cases varied between 210 and 785 grams with an average weight of about 460 grams The results of these measurements are shown in Table 7

The coronary arteries in all cases were only slightly arteriosclerotic The myocardium was firm with occasional whitish spots of about the size of rice grains There was a peculiar malformation on one of the pulmonary cusps in Case 1 the posterior cusp having a short but thick papillary muscle (Fig 5) the other pulmonary cusps were normal No changes were observed in the remaining cases on the right side in the cusps or leaflets and there was no evidence of any other malformation of the heart

Congestion in the other organs was noted in all cases Case 1 had cirrhosis of the liver and Case 10 emphysema an old carotid thrombus and minor cerebral softenings (status lacunaris) Case 12 had recent extensive softening of the brain

Histologic examination of the myocardium revealed a number of small diffusely spread connective tissue scars The muscle bundles particularly in the muscular bulk were thicker than normal and appeared to pursue an irregular course but no tumour structures were observed Sections from the anterior mitral leaflet showed newly formed connective tissue but no traces of inflammation No Aschoff bodies were evident in the leaflet or myocardium

Table 6

Cases	Heart weight g	Septal bulk thickness cm	Myocardial thickness cm
1	510	4	2
9	425	1.5	1
10	425	—	—
11	815	3	1.5
12	815	3.7	1.7

Discussion

It would appear to the authors that the diagnosis of this condition can only be established through heart catheterization and angiocardiography. The risks involved in catheterization, however, should be borne in mind. There have been several reports of serious arrhythmia, a complication that is most common during the intraventricular passage of the catheter on the left side. There were some cases of serious arrhythmia in our material and we have had one fatality during the passage of the catheter through the right ventricle but we have only noted extra systoles during the catheterization of the left ventricle.

An exact diagnosis is necessary in these cases in order to avoid that surgery is performed in the belief that valvular stenosis is present. The increased risk incurred in catheterization would therefore appear to be justified. If the catheter does not pass the stenosis readily, no undue force should be applied and angiocardiography with the catheter tip above the stenosis should be performed. We are uncertain whether another type of catheterization might be of greater advantage, e.g. transseptal or the percutaneous left ventricular puncture as we have no personal experience of these methods.

Roentgenology. The positive findings in angiocardiography that indicate muscular subaortic stenosis are characterized by

1. Varying stenosis in the left ventricle 20 to 31 mm below the aortic ostium,
2. Ring like hypertrophy of the musculature corresponding to the septal and anterior part of the left ventricular wall,
3. The posterior part of the stenosis consists of the anterior mitral leaflet which may be (a) elongated, (b) thickened, (c) less mobile, (d) more bulging into the outflow tract.

Table 7

	Leaflet length mm	Chorda length mm	Total length mm
Case 1	30	28	58
Case 11	25	24	49
Mean values of control cases	23	19	42



Fig 5 Case 1 Papillary muscle to one of the pulmonary cusps

Further diagnostic evidence might consist in

4 Regurgitation to the left atrium which is enlarged
5 Hypertrophy of the left ventricular wall
6 Hypertrophy of the papillary muscles
7 Widened coronary vessels
8 Absence of calcifications in the aortic cusps
9 No post stenotic dilatation of the ascending aorta

Catheterization No systolic pressure gradient between the aorta and the ventricle could be recorded in four of the eight cases A second pressure re cording was made in one of the cases before operation this revealed a large systolic gradient and it is probable that the first result was obtained from a catheter position above the stenosis The absence of a gradient in the other three cases might thus have been due to a technical mistake i e the catheter might not have passed the stenosis Another explanation may have been that one of the side holes in the catheter was located above the stenosis A false diagnosis may thus be made if angiocardiography is not performed

Studies of infundibular pulmonary stenosis (RODBARD & SHAFFER 1956 JOHNSON 1959) have revealed pressure curves of the same type as in the present cases These authors observed that the contraction of the infundibulum, which occurred later than did the rest of the right ventricle appeared at the same time as the pressure fall in the curve from the pulmonary artery The connection

Table 6

Cases	Heart weight g	Septal bulk thickness cm	Myocardial thickness cm
1	510	4	2
9	425	1 5	1
10	425	—	—
11	815	3	1 5
12	815	3 7	1 7

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that was synchronous with early systolic ejection The volume again increased slightly towards the end of systole a continuous increase in volume is normally followed by a decrease in the latter part of systole and in diastole A delayed curve is seen in anatomically rigid stenosis of the valvular or fibrous subvalvular type (Fig 1) and is the result of the continuous resistance to ventricular output from the very beginning of the systole and the mode of action of the left ventricle during systole The curve described in muscular subvalvular aortic stenosis is difficult to explain but agrees with the assumption that a con traction with stenosis of the outflow tract commences in mid systole

Both pressure and volume pulse curves thus differ in muscular subvalvular aortic stenosis from those found in anatomically rigid stenosis and constitute an important differential diagnostic sign

BROCKENBROUGH et coll observed the arterial pulses following extra systoles Decreased pulse amplitude in the systole following an extra systole was noted in cases of muscular subvalvular aortic stenosis but in normal cases and in cases of anatomically rigid valvular or subvalvular stenosis the pulse amplitude increased The condition is explained by Starling s law After an extra systole with a compensatory pause the left ventricle increases in volume on account of the prolonged diastole The next strokes begin with greater diastolic volume and the contraction is thus more powerful Since the stenosis is of a muscular type, obstruction to the output increases even further and subsequently the pulse amplitude decreases This phenomenon may also be an explanation of the increased risk involved in catheterization of muscular subaortic stenosis The authors did not succeed in registering the pressure in connection with extra systoles in any of their cases but the phenomenon may be of importance in the differential diagnosis

Pathology All the cases presented the typical macroscopic appearances of a thick muscular bulk situated in the ventricular septum It must be remembered, however that the identification of subvalvular aortic stenosis of the muscular type is difficult and it is probable that a certain number of cases with this condition can never be diagnosed by pathologic examination Of major im portance is whether the heart stops in diastole or systole and the degree of rigor mortis MORROW & BRAUNWALD described cases that on well founded indications had been operated upon for presumed aortic stenosis cardiac arrest was enforced in diastole during the operation and no changes were found either in the aortic cusps or in the outflow tract

The macroscopic appearances in this form of subvalvular aortic stenosis are reminiscent of the changes in a large heart in cases of systemic hypertension in which a muscular bulk in the characteristic position is also observed BROCK has described three cases which developed subvalvular stenosis during pro tracted treatment for hypertension and we also believe that subvalvular stenosis may arise from systemic hypertension It is hardly possible to distinguish these

between the pulmonary artery and the right ventricle at the end of systole was constricted, in other words, the stenosis successively increased during the contraction of the heart muscle. The authors cited reached the conclusion that the active contraction of the hypertrophic infundibulum was the cause of the stenosis and the pressure gradient.

The curves and the angiocardiographic observations seem to indicate that the same conditions prevail in muscular subvalvular aortic stenosis. The course of events may be described as follows.

A ventricular contraction takes place at the beginning of systole in the usual way. This brings about the opening of the aortic cusps, and ejection of blood into the aorta commences normally. No stenosis seems to exist in early systole and the course of the pressure curves from the aorta and the left ventricle are identical. The pressure curve from the ventricle rises and the curve from the aorta falls at the time when the constriction of the outflow tract becomes maximal. In the roentgenograms from midsystole the outflow tract is seen to contract and, at the same time as the septal part bulges into the anterior part of the conus, the anterior mitral leaflet bulges in from behind. A successive constriction thus takes place simultaneously with the cardiac contraction although in this phase the contraction at the apex is not yet entirely completed. These observations have been made in a number of roentgenograms and may explain the typical pressure curves obtained. Pressure curves in cases of valvular aortic stenosis are different, as the pressure maximum appears synchronically above and below the stenosis, this maximum is delayed in relation to the beginning of systole in both curves (see Fig. 1).

The writers consider that the mode of contraction in muscular subvalvular aortic stenosis, with a successively appearing constriction of the outflow tract by muscular contraction, is characteristic of the hemodynamics of this condition.

A septal hypertrophy of this type may also be expected to affect the corresponding part of the right ventricle, i.e. the infundibulum. The septum forms the wall between the right and left outflow tracts and, when hypertrophic, may protrude on both sides. BRAUNWALD et coll. found several cases of bilateral stenosis in their material of muscular subaortic stenosis. The present authors were able to show minor pressure gradients between the right ventricle and the pulmonary artery in three of their cases, in two of these the course of the curve was similar to those on the left side of the heart, indicating similar dynamics. A post mortem examination was performed in one of the cases (Case 1) but it is doubtful whether the findings explained the curves that were observed.

A pathologic mode of contraction of the left ventricle means that a change in the volume pulse curve may be expected. This was confirmed in the only case in which a technically satisfactory subclavian curve was registered. A rapid fall in volume in the middle of systole was recorded after an initial wave

described two cases in which this leaflet was abnormally placed, being inserted anteriorly and medially STAMPBACH & SENN suggested that the mitral changes may be the outcome of healed endocarditis Certain authors it is true have not mentioned any changes in the mitral leaflets but it emerges from the illustrations in their publications that at the least the anterior mitral leaflet was changed

Our investigation has shown that the anterior mitral leaflet is elongated in this condition and that in mid systole the leaflet bulges into the outflow tract Even if there were no muscular hypertrophy in the ventricular septum the leaflet itself would cause a certain obstruction to the outflow tract which in turn would be followed by compensatory cardiac hypertrophy The outflow tract at this point in mid systole has started to contract the region of the apex on the other hand is in a later contraction phase, and on account hereof hypertrophy in the apex region can only be slight The outflow tract is in an earlier phase of contraction and hypertrophy can therefore occur to a greater degree the more hypertrophic it becomes the greater the stenosis and a vicious circle is produced

We thus consider the primary factor in muscular subaortic stenosis to be a change in the anterior mitral leaflet This may either take the form of an abnormal insertion or an elongation of the leaflet healed endocarditis might account for an abnormal insertion but hardly for an elongation A congenital malformation may be the reason for an elongation of the leaflet There is an embryologic connection between the infundibular part of the right ventricle the upper part of the ventricular septum and the anterior mitral leaflet These parts are thought to be formed of the bulbus cordis (KEITH) Malformation in one of these regions may thus be present together with a malformation in one of the other regions In this respect Case 1 — with the individual 'papillary muscle to one of the pulmonary cusps is illustrative Further support for the malformation theory are those cases described in the literature in which the condition was hereditary (HOLLMAN et coll BRENT et coll)

Treatment The conservative treatment of this condition is unlikely to achieve satisfactory results Many authors consider that any surgical procedure will fail although reports of successful operations have recently appeared (BRAUNWALD et coll KIRKLIN et coll) Different methods have been employed in attempts to reduce the hypertrophic muscle in the septal region, either through an incision in the muscular bulk or by removal of part of the muscle These operations have resulted in slight improvement but a manifest systolic pressure gradient has persisted From what has been stated concerning the pathogenesis of the condition it would appear worthwhile to consider the possibility of a plastic operation on the anterior mitral leaflet Mitral valve prosthesis might constitute an alternative procedure

Prognosis This is obviously difficult since the condition has been known of

cases post mortem from true subvalvular stenosis by the appearances of the muscular bulk. Case 12 seems to belong to this group.

The medial part of the anterior mitral leaflet had fused with the ventricular septum in Case 10, and as a result the leaflet was situated medially. Similar cases of abnormal insertion of this leaflet have been described by BJORK et coll.

Histologic examination of the muscular bulk revealed thick muscular bundles with an apparently irregular course. Findings such as these are given pathogenic significance in cases described in the literature. It does not, however, appear remarkable that muscular bundles are thickened in a heart which is considerably hypertrophic, or that these bundles have a somewhat irregular course since obviously their orientation in the septal region differs from that, in the apex region, for example.

Considerable thickening of the anterior mitral leaflet was observed in four *of the five post mortem cases but in none of these had the anterior* leaflet fused with the posterior leaflet. The reason for this thickening is difficult to explain, though it may of course be the outcome of a healed, mild endocarditis. The measurements of the anterior mitral leaflet clearly indicated, however, that this leaflet was longer in cases of subvalvular aortic stenosis than in control cases, this was proved both anatomically and roentgenologically. It was further evident from the roentgenograms that the anterior mitral leaflet bulged more than is normal. The leaflet is thus subjected to greater strain in the blood stream than under normal conditions and it seems reasonable to assume that this increased strain on the leaflet causes the thickening. This hypothesis is further supported by the observation that in only one of the four cases did the posterior mitral leaflet show a similar, though less marked, thickening.

Mitral insufficiency was observed in half the number of cases subjected to angiocardiography and in a large number of cases described in the literature. It seems very probable that the changes in the anterior mitral leaflet constitute the anatomical foundation for the insufficiency.

Pathogenesis The pathogenesis of this condition is not clear. As the present writers have already stated, they agree with BROCK that subvalvular stenosis may result from protracted hypertension but believe that this is probably the *cause only in a minority of the total number of cases of muscular subvalvular* stenosis.

Two main pathogenetic aspects have been discussed in the literature. One group of authors has devoted special attention to the muscular bulk in the ventricular septum (GOODWIN et coll, TEARE). The irregular muscle bundles that have been observed histologically have been regarded as a congenital malformation. In view of what has been stated previously the present authors cannot support this argument. The other group of authors has devoted particular attention to the anterior mitral leaflet. BJORK et coll, for example,

described two cases in which this leaflet was abnormally placed being inserted anteriorly and medially STAMPBACH & SENN suggested that the mitral changes may be the outcome of healed endocarditis Certain authors it is true have not mentioned any changes in the mitral leaflets but it emerges from the illustrations in their publications that at the least the anterior mitral leaflet was changed

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Prognosis This is obviously difficult since the condition has been known of

for only a relatively short time Sudden death in early years is described as common, although there are subjects who have reached an old age No conclusions can be drawn from the cases described in this communication, even though in some of them the condition has been present from an early age The determining factor is the width of the stenosis and its possible increase A careful follow up with control pressure recordings and angiocardiography would appear to be necessary to evaluate the natural course of the condition

Addendum in the proofs

Since the article was written a post mortem examination has been performed of a 15 year old boy suffering from the condition described The roentgenograms which were obtained in another hospital did not allow the anterior mitral leaflet to be measured The leaflet at post mortem was found to be elongated (leaflet length 25 mm chorda length 28 mm) We regard this case to constitute further evidence in support of our suggestion that changes in the anterior mitral leaflet is the causative factor

SUMMARY

Twelve cases of subvalvular aortic stenosis of the muscular type 8 of which were investigated by heart catheterization and cardioangiography are described Autopsy was performed in 5 of the cases The investigations revealed characteristic anatomical and roentgenologic changes the anterior mitral leaflet was longer in cases with this condition than in the control cases The authors consider the muscular bulk in the ventricular septum to be a secondary effect while changes in the anterior mitral leaflet are of decisive importance

ZUSAMMENFASSUNG

Es werden 12 Fälle von muskulär bedingter Aortenstenose beschrieben von denen 8 durch Herz Katheterismus und Angiokardiographie untersucht wurden Eine Autopsie wurde bei 5 dieser Fälle durchgeführt Die Untersuchungen ergaben charakteristische anatomische und röntgenologische Veränderungen Die anteriore Mitralklappe war länger als in Vergleichsfällen Die Verfasser nehmen an dass der muskuläre Wulst des Septum ventriculorum ein sekundärer Effekt ist während den Veränderungen in der anterioren Mitralklappe eine entscheidende Bedeutung zukommt

RÉSUMÉ

Les auteurs décrivent douze cas de sténose aortique sous valvulaire de type musculaire dont 8 ont été examinés par cathétérisme cardiaque et par angiocardiographie Cinq de ces cas ont été autopsiés Ces examens ont montré des aspects anatomiques et radiologiques caractéristiques La valve mitrale antérieure est plus longue dans cette affection que chez les sujets témoins normaux Les auteurs pensent que la saillie musculaire de la cloison interventriculaire est un phénomène secondaire alors que l anomalie de la valve mitrale antérieure a un importance primordiale

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FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR PROF OLLE OLSSON), UNIVERSITY HOSPITAL, LUND, SWEDEN

INTRACRANIAL INVOLVEMENT IN EPIDERMOID AND DERMOID TUMORS OF THE SKULL

by

STEN CRONQVIST and MARK H WHOLEY

Epidermoid tumors and dermoid cysts may lie within the bones of the skull or be situated intracranially or intracerebrally Both are of congenital origin and emanate from displaced embryological cell rests, the dermoid cyst contains structures from the entire dermis while the epidermoid arises only from ectodermal rests Their growth is non infiltrating and extremely slow, but when they are confined within the bone the diploic space is eventually widened and the tables of the skull are eroded Roentgenograms of the skull most often demonstrate a polycystic defect with smooth sclerotic margins of bone condensation The growths occasionally appear as clustered irregular smaller defects separated from each other by dense irregular trabeculations and, since they always contain cellular debris, it is not uncommon to find associated dystrophic calcification lying either centrally or in the capsule Teeth and bone formation may also be observed in dermoid cysts Encephalography will demonstrate characteristic, streaked and irregular collections of gas within and around the process when the growths are localized intraventricularly or in the basal cisterns (KREIG 1936, DYKE & DAVIDOFF 1937)

The defect in the calvarium produced by an intradiploic epidermoid is,

Submitted for publication 16 July 1962



Fig 1 Case 1 Slightly irregular mainly occipital bone defect with well defined sclerotic margins Eroded bone remnants in upper part and a small sequestrum centrally

however not an accurate index of the true tumor size for intracranial extension of the tumor may be considerably greater than the bone defect would suggest The actual tumor size will be apparent in conventional films only in those cases in which calcifications of the capsule are present A determination of the degree of extension will in other cases however not be possible before operation without angiography or encephalography The value of these methods of investigation of intradiploic epidermoids and dermoids cysts is shown by the two characteristic cases that are now reported

Case reports

Case 1 (Figs 1 to 4) Woman aged 49 with four years history of attacks of vertigo vomiting and tinnitus in the left ear and during the last previous few months ataxia On admission she had an unsteady gait a positive Romberg sign and loss of hearing of the neurogenic type on the left side

Roentgen examination A large well demarcated defect with sclerosed margins was present in the right occipital and lower part of the right parietal bone no calcifications were evident

Lumbar encephalography The fourth ventricle as well as the vallecula were displaced towards the left no displacement of the cisterns within the tentorial notch or around the brain stem

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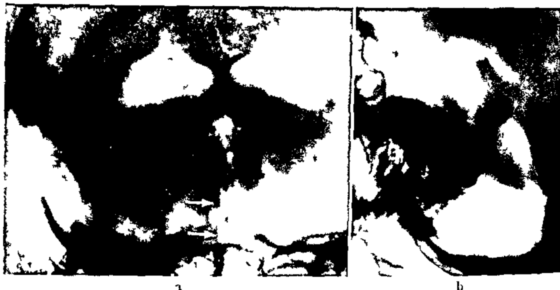
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a b

Fig 2 Case 1 Encephalography a) P a view Laterally displaced fourth ventricle b) Lateral view No displacement of fourth ventricle or aqueduct

right superior cerebellar artery was displaced medially the inferior posterior cerebellar artery being shifted to the left of the midline the cerebellar veins in the lateroposterior parts of the posterior fossa were displaced medially the smaller veins being deformed into an arch by the expansive process

Diagnosis Epidermoid or dermoid with intracranial involvement

Operation Epidermoid

Case 2 (Figs 5 and 6) Woman aged 50 with six months history of a rapidly growing mass in the left parietal region accompanied by headache No other symptoms or signs on admission

Roentgen examinations Skull A large cystic bone defect with sharply sclerosed margins was evident in the left parietal bone small irregular bony islands extended across the middle of the defect and a large soft tissue mass bulged outside it the pineal body was calcified and displaced to the right

Lumbar encephalography The upper and posterior parts of the septum pellucidum and the third ventricle were displaced to the right of the midline the left lateral ventricle being shifted medially and the roof of the trigone downwards the left temporal horn was flattened and the posterior part displaced medially the left ambient cistern was straightened

Diagnosis Epidermoid or dermoid of the skull with extra and intracranial involvement

Operation Dermoid cyst

Discussion

Epidermoid tumors are sometimes referred to in the literature as cholesteatomas due to the fact that they may contain cholesterin This has unfortunately produced some confusion since the term cholesteatoma generally refers to the true granuloma of the temporal bone associated with chronic suppurative otitis media Furthermore the stratified squamous epithelium is the patho

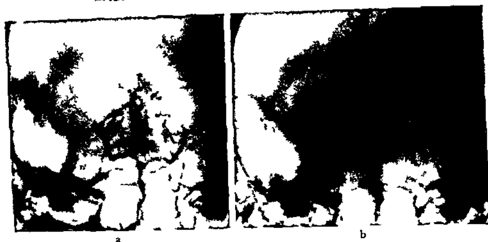


Fig 3 Case 1 Vertebral angiography a) Smaller branches from superior cerebellar artery displaced medially b) Venous phase Superficial veins that are displaced medially define the medial border of an expansive process

gnomonic feature of the epidermoid and not the cholesterin The interchangeable use of these terms is consequently not to be recommended if the true meaning is to be maintained

The differential diagnosis between an epidermoid and a dermoid is not possible when the primary site is the diploic space Pathologic studies have shown that different sections from the wall of the same tumor may be dermoid in one section and epidermoid in another (MONTGOMERY & FINLAYSON 1934)

One characteristic of epidermoids and dermoids arising in the diploic space and extending toward the cranial cavity is that they remain extradural Diploic epidermoids and dermoids are however because of the characteristic appearances rarely confused with other cranial defects Exceptionally when these growths lie in the frontal sinus region less marginal bone condensation may occur and the appearances may suggest a mucocele A meningocele and a meningoencephalocele in children give rise to well demarcated rounded defects with a sclerotic margin They are however situated close to the midline in the regions of the occipital and frontal accessory fontanelles A similar change may be caused by a leptomeningeal cyst that may follow a fracture of the skull in children but evidence of a solution of continuity will indicate the correct diagnosis Defects caused by eosinophilic granuloma occasionally present marginal sclerosis these are however small and are rounded or oval in shape Meningeomas may sometimes produce a bone defect but then the border is uneven and irregular The differential diagnosis in these cases may be facilitated by the presence and form of eventual calcifications although these seldom occur



Fig. 1. Case 1. Carotid angiography. Displacement of external vessel by process within bone; no pathologic vessels.

in meningeomas they will appear as closely packed small nodules or granules. Calcifications in epidermoids and dermoids, on the other hand, are a frequent finding; they are large, irregularly shaped, and are distributed throughout the tumor or the capsule wall.

A large intracranial extension may be found at operation for radical removal of these growths (PEYTON & BAKER 1942, MAC CARTY et coll. 1959). Their complete extirpation may prove difficult and recurrences under such circumstances are not unlikely (SCHWARTZ 1941). Angiography and encephalography should therefore always be employed in these conditions when changes in the calvarium are associated with symptoms or signs to suggest intracranial involvement. A determination of the extent of the tumor as shown by the displacement of cerebral structure will prove of essential value in the assessment of the indication for operation.

Acknowledgement

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Fig 5 Case 2 Lateral view La ge well defin d defect w th scl rot c marg ns in parietal bon e oded irregular bone remnants in lower part



Fig 6 Case 2 Encephal graphy D placed and t lted midlin truct res post r or p rt of l ft lat ral nt icle di placed m d ally and downw rds und th f l temporal horn flattened and d placed downwa d

SUMMARY

The investigation of intradiploic epidermoid tumors and dermoid cysts by angiography and encephalography is discussed and two characteristic cases are described

ZUSAMMENFASSUNG

Die Diagnose der intradiploischen Epidermoide und Dermoidcysten mittels Angiographie und Encephalographie wird besprochen und zwei einschlägige Fälle werden beschrieben

RÉSUMÉ

Les auteurs étudient l examen angiographique et encéphalographique des tumeurs epidermoides intradiploiques et des kystes dermoides et en décrivent deux cas caractéristiques

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FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR TH RASMUSSEN) THE CENTRAL HOSPITAL HJØRRING DENMARK

RENAL HAEMANGIOMA DIAGNOSED PREOPERATIVELY BY SELECTIVE RENAL ANGIOGRAPHY

Report of a case

by

J BONE ANDERSEN and TH RASMUSSEN

Haemangioma of the kidney is extremely rare RILEY & SWANN (1941) found no case in 13 219 autopsies and BELL (1938) in 30 000 autopsies observed only one WALLER et coll collected 78 cases from the world literature up to 1955

These growths which are benign may affect the cortex medulla or a sub epithelial area of the pelvis They are generally venous but may be arterial or mixed veno-arterial they may be capillary but are generally cavernous BIERRING (1955) reported that the largest renal haemangioma on record measured 12 5 5 cm — *although the formations seldom exceeded 1 to 2 cm in diameter* — and that a number of those which had given rise to haematuria had been so small as to be difficult to demonstrate macroscopically

The main sign is haematuria ranging from a mild condition, with occasional red cells present in the urine to alarming haemorrhage It is the pelvic haemangioma and particularly the papillary haemangioma that following erosion of the urinary tract epithelium produces the haematuria Haematuria may be the only sign but it may also frequently be associated with more or less severe low back pain due to the formation of clots in the renal pelvis and ureter

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Fig. 1. Operative specimen. Subendothelial discolorations in central and superior part of the renal pelvis indicate the angioma.

The diagnosis has usually been made postoperatively after nephrectomy for probable malignancy. *The ordinary clinical examination is of little aid*, and there are no characteristic roentgenologic signs. Pyelography may show indentations, or deformity of a calyx or the pelvis. However, only major haemangiomas manifest themselves in this way, as a rule, these appearances merely represent clots.

The introduction of selective renal angiography ought to afford a possibility of establishing the diagnosis without resort to nephrectomy, at least in some cases.

Case report

The patient was a woman aged 59 with no past history of urinary symptoms. In May 196[illegible] she was admitted with haematuria and increasing pain in the right loin. Hb 114 g/l, serum creatinine 9.8 mg/l. On cystoscopy almost pure blood was coming from the right ureteric orifice, no other abnormality noted.

Urography. No excretion on the right side, normal appearances on the left. Pyelography on the right side was performed and showed a defect in the contrast filled pelvis considered to represent a clot or possibly a mural pelvis tumour.

Right selective renal angiography. A plum sized defect in the lower renal pole and recurvation of the corresponding segmental arteries suggested the presence of an avascular cyst. An area of densely placed vessels, considerably coiled and tortuous, was evident in the central area. Radiologic diagnosis: renal angioma with a cyst in the lower pole of the kidney. Right nephrectomy was performed. The postoperative course was uneventful and the patient wa
in good health.



Fig. 2. a) Early arterial phase. The contrast medium fills the highly tortuous vessels of the angioma in the central part of the kidney; massive density of medium represents the capillaries and partially overlies the region. b) Early capillary phase. The angioma still stands out in sharp contrast to the normal renal parenchyma.

The macroscopic examination had shown subendothelial, reddish discoloration at the site shown to be highly vascular (Fig. 1). The histologic examination established an angioma of the renal pelvis, renal cyst, and chronic pyelonephritis. The angioma consisted predominantly of large vessel lumina but without cavernous architecture; the vessels were built up partly as arteries and partly as veins (V. Eskelund).

Discussion

The angiographic technique consisted of the percutaneous introduction of a catheter into the femoral artery, the renal artery being catheterized under fluoroscopic control with a television image intensifier. 8 ml Urografin 60 % were injected under a pressure of 28 lb/in² by an automatic pressure syringe. A manually operated cassette tunnel was employed.

The renal artery of average calibre with normal central branches was well filled in the arterial phase. There was also rapid filling of a coil of blood vessels in the central part of the kidney, which occupied an area of 3 × 4 cm and was partially superimposed over the pelvis and middle calyces; this stood out as a well demarcated process and consisted of numerous densely placed highly



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Right selective renal angiography A plum sized defect in the lower renal pole and recurvation of the corresponding segmental arteries suggested the presence of an avascular cyst An area of densely placed vessels considerably coiled and tortuous was evident in the central area Radiologic diagnosis renal angioma with a cyst in the lower pole of the kidney Right nephrectomy was performed The postoperative course was uneventful and the patient was discharged in good health



Fig 7 a) Early arterial phase The contrast medium fills the highly tortuous vessels of the angioma in the central part of the kidney massive density of medium represents the capillaries and partially overlies this region b) Early capillary phase The angioma still stands out in sharp contrast to the normal renal parenchyma

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tortuous vessels of uniform calibre and about 1 mm wide A smaller triangular area, the density of which was much more marked than that of the renal parenchyma, was apparent supero laterally (Fig 2a)

Both structures were unchanged in the early capillary phase and stood out *in strong contrast to the surrounding parenchymal filling* The individual vascular lumina were still discernible at this stage, when the medium in other renal vessels of this calibre had disappeared (Fig 2b) The process had disappeared at a later stage of the parenchymal phase as well as in the venous phase

The considerable accumulation of contrast medium and the delayed emptying must be interpreted as being the result of a relative reduction in the rate *of flow in the* process produced by a dilatation of the volume of the vascular bed in this area The parenchyma like density of medium in the smaller, lateral area at an early stage of the arterial phase must be taken to indicate that in this region the process consisted predominantly of capillaries

The possibility of a malignant, highly vascular tumour was considered in the differential diagnosis The sharp demarcation, densely arranged vessels of uniform calibre, regular outlines, and the marked intensity of the medium in the capillary part *of the growth,* were *however* recognised as being *features that* do not occur in malignancy

SUMMARY

A case of haemangioma of the renal pelvis in which the diagnosis was made preoperatively by selective renal angiography is reported

ZUSAMMENFASSUNG

Es wird uber einen Fall von Haemangiom des Nierenbeckens berichtet die Diagnose konnte vor der Operation mittels selektiver Angiographie gestellt werden

RÉSUMÉ

Présentation d un cas d hémangiome du bassinet du rein dont le diagnostic a été fait avant l opération par angiographie rénale sélective

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FROM ISTITUTO DI RADIOLOGIA (DIRECTOR PROF O BUSINCO) DELL UNIVERSITÀ DI CAGLIARI, ITALY

VENOLYMPHATIC COMMUNICATION OBSERVED DURING LYMPHOGRAPHY WITH AN OILY CONTRAST MEDIUM

A case report

by

F MARROCU and F COSSU

The existence of direct venolymphatic communications has always remained a matter of doubt despite a great deal of research, and since the beginning of the present century it has been discussed among others by RUSZNYÁK FÖLDI & SZABÓ and MALEC KOLC ZÁK & FISCHER

The phenomena in the case now reported were observed during the performance of lymphography with an oily contrast medium and provide evidence that such communications exist at least under pathologic conditions

Case report

A man aged 63 was treated with radiotherapy for an endothelioma (histologically confirmed) in the right inguinal region After *improvement* lasting nine months a hard fixed mass was evident in the right lower abdominal quadrant Lymphography was performed by injection of ultra fluid Lipiodol into a *lymphatic vessel* on the medial aspect of the dorsal surface of the right foot by the Kinmonth technique

The lymphatic vessels comprising *the medial* group in the leg thus injected (Fig 1a) were slightly enlarged in diameter they were numerous but followed a regular course After the in

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a b

Fig. 1. a) Numerous and slightly enlarged lymphatic vessels on the medial aspect of the leg. b) After injection of 4 ml U.F. Lipiodol a lymph node of semilunar shape in the marginal sinus is contrast filled. The contrast medium has not reached farther than the inguinal lymph nodes.

jection of 4 ml U.F. Lipiodol the vessels in the marginal sinus of an inguinal lymph node, probably the site of a neoplastic process, began to fill, and as the injection proceeded other lymph nodes were also outlined (Fig. 1b); the lymphatic vessels at the upper part of the limb were thin and very numerous.

After injection of 10 ml contrast medium a fine lymphatic network appeared over the inguinal region. Soon after this a vein 8 cm long and 8 to 9 mm wide in the middle third of the thigh near the medial aspect of and parallel to the femur was filled; its lower end terminated abruptly (Fig. 2, a and b).

The lymphatic network remained unchanged after the injection of 12 ml contrast medium while the vein was only faintly visible. An ovoid shaped collection of contrast medium appeared in the inguinal region and this was interpreted as representing the terminal part and valves of the same venous vessel (Fig. 2c). These appearances persisted for about an hour. The contrast medium tended to collect in the superior part of the leg and disappear from the lower part.

The patient refused phlebography.

Discussion

This was a case of obstruction of the lymphatic flow, with secondary congestion of the lymphatics and moderate enlargement of the collector vessels of the leg; similar vessels in the thigh were increased in number, and a fine net



Fig 2 a) After injection of 10 ml Lipiodol numerous and thin lymphatic vessels on the medial aspect of the thigh are seen. A lymph node and a vein are also contrast filled. b) After injection of 11 ml Lipiodol increased filling of the vein which now appears with valves. Distally a lymphatic vessel describing a curve seems to connect with the vein. c) After injection of 12 ml Lipiodol the venous vessel is almost emptied of contrast medium.

work which normally is not seen was outlined. The injection of this fine net work together with that of a venous vessel, took place following efforts to increase the injection pressure of the contrast medium in order to force the obstruction at the inguinal region and reach the other lymphatic regions via a possible anastomotic system.

If a water soluble medium had been used and as sometimes happens extravasation into the tissue had taken place such a medium unlike one with an oily base might have been readily reabsorbed through the veins, and a phlebogram could have been produced (MARLEY & MORONE).

It would thus appear that a direct communication existed between the lymphatic and venous systems its demonstration by the injection of contrast medium being aided by the congestion created by the obstruction in the inguinal region. A marked slowing down of the circulation velocity in the vein that was injected was also probable the oily contrast medium would otherwise not have accumulated in the vein but would have flowed away fast enough to prevent the phlebographic effect from taking place.

SUMMARY

A case is described in which a venolymphatic communication was demonstrated by lymphography with an oily contrast medium

ZUSAMMENFASSUNG

Ein Fall wird beschrieben in dem die Lymphographie mit einer öligen Kontrastsubstanz eine Verbindung eines Lymphgefässes mit einer Vene zeigte

RÉSUMÉ

Description d un cas ou la lymphographie avec un moyen de contraste huileux a mis en évidence une communication veino lymphatique

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FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR CURT JOHANSON),
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ILEO-ILEAL INVAGINATION IN ADULTS DUE TO MECKEL'S DIVERTICULUM

Report of two cases

by

ANDERS HEMMINGSSON

Invagination of the small intestine in adults is usually chronic although sometimes recurrently acute and consequently does not give rise to total obstruction in so called acute ileus (13) The symptoms and signs are uncharacteristic and consist of recurrent abdominal pain constipation and diarrhea, as well as loss of weight and melena often of several months duration (27) The clinical diagnosis is therefore difficult to establish

The mechanism of the genesis of invagination was described in the basic work carried out by LAURELL (1932) and by NORDENTOFT & HELLMER (see HELLMER 1948) A tumour often benign and pedunculated is usually the causal factor of the intussusceptum in approximately a third of cases (8) Meckel's diverticulum is said to be the next most frequent cause (13 14) LAURELL in 1929 published 1932) was the first to diagnose ileo-ileal invagination produced by Meckel's diverticulum by means of a barium enema He suggested that the examination should be carried out while the patient was suffering from an attack of pain because the apex of the intussusceptum may then have pene-

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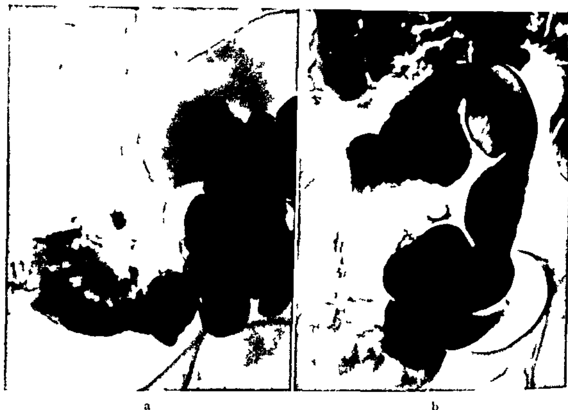


Fig 1a) Case 1 Prestenotic ileal coil with longitudinal mucosal folds symmetrical and conical constriction of canal of intussusceptum b) Case 2 Characteristic appearance of an ileo ileal invagination

trated through the ileocaecal valve and produced signs of an impression, as happened in his case (20)

Meckel s diverticulum occurs with a frequency of 2 % to 4 % and its incidence in men is three times that in women (30, 32) It produces signs that lead to operation in 20 % to 25 % of cases (4 34), 17 % of which are due to invagination (14, 32) The frequency of ileo ileal invagination represents 9 % to 14 % of all intestinal invaginations Between 2,5 % to 5 % are caused by Meckel s diverticulum and occur primarily in children (12, 14), at least 80 cases after puberty were reported, however, in 1949 (11)

Invagination of Meckel s diverticulum into the lumen of ileum may occur This acts as any polypoid mass and may cause intussusception as in the following two cases

Case reports

Case 1 A man aged 30 with intermittent colicky pain in the lower part of the abdomen vomiting constipation alternating with diarrhea anorexia and loss of weight for six months He had earlier had similar intermittent symptoms and 2 years before operation had had melena The clinical examination displayed diffuse tenderness in the lower part of the abdomen

Roentgen examination of the alimentary tract suggested obstruction in the distal part of the ileum The prestenotic ileal coil was dilated and raised in the shape of an inverted U the folds of the mucous membrane being smoothed out this coil tapered symmetrically and conically to a width of only a few millimeters The mucous membrane was preserved and folded longitudinally in a canal that was filled approximately 4 cm aborally The diagnosis of an invagination was made The small intestine distal to the obstruction was of ordinary width and filled with contrast medium the main mass of which after 8 hours lay in the colon (Fig 1a)

Operation Chronic invagination with an inverted Meckel s diverticulum *Histology* Chronic inflammatory changes in a diverticulum with an ulcer scar and at the apex possibly an active ulcer The patient recovered completely

Case 2 A woman aged 29 with melena and epigastrical pain radiating to the back for 10 weeks The pain had lasted for about 6 to 7 hours and had been accompanied by vomiting diarrhea anorexia and loss of weight On admission there was tenderness to the right of the umbilicus

Roentgen examination No changes in the large bowel or insufficiency of the ileocaecal valve were found cholecystography was negative A barium meal examination showed the stomach and duodenum to be normal but there was some delay in the passage of the contrast medium through the small intestine Obstruction was evident in the distal part of the ileum The prestenotic coil was dilated and its mucosal folds were smoothed out peristalsis was increased and the coil was raised in the shape of an inverted U On compression it was constricted symmetrically and conically in an aboral direction so that it became a narrow streak about 10 cm in length with preservation of the mucous membrane and longitudinal mucosal folds It showed no peristalsis contrast filled concentric rings centred on the narrow contrast streak, were observed around it — typical appearance of an invagination The contrast medium distal to the obstruction proceeded into the normal parts of the small intestine and after 7 hours most of it had entered the colon (Fig 1b)

Operation Chronic invagination 20 to 30 cm long in the distal part of the ileum with an 8 cm inverted Meckel s diverticulum

Histology Meckel s diverticulum with ectopic ventricular mucous membrane and peptic ulceration as well as ectopic pancreatic tissue in the wall of the diverticulum Complete recovery

Discussion

Since invagination of the small intestine in adults is usually chronic a conventional roentgenographic survey of the abdomen may not disclose an ileus FRIMANN DAHL however considers that it is highly probable that a negative survey picture excludes invagination (9) The same opinion is held by MIDDLEMISS in 62 cases of invaginations in children he obtained in every case signs of ileus or invagination in survey films (22)

In addition to evidence of obstruction signs of its cause may sometimes be apparent in survey roentgenograms These may consist of invagination proper (29 33) gas in a coil that is stenosed conically (15 33) and gas in the canal of the intussusceptum (22 29) If the invagination is situated in the colon or the ileocaecal valve is insufficient gas may also surround the apex of the invagination or penetrate into the sheath of the intussuscipiens (15 28 29 33)

No survey films were obtained in the cases described as they were not considered acute

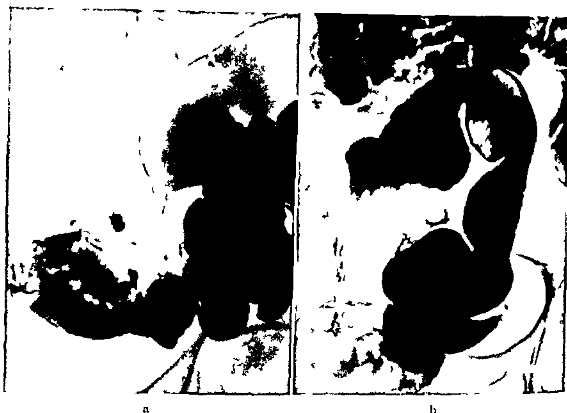


Fig. 1a) Case 1. Prestenotic ileal coil with longitudinal mucosal folds, symmetrical and conical constriction of canal of intussusceptum. b) Case 2. Characteristic appearance of an ileo-ileal invagination.

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Invagination of Meckel's diverticulum into the lumen of ileum may occur. This acts as any polypoid mass and may cause intussusception as in the following two cases.

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Case 1. A man aged 30 with intermittent colicky pain in the lower part of the abdomen, vomiting, constipation alternating with diarrhea, anorexia and loss of weight for six months. He had earlier had similar intermittent symptoms and 2 years before operation had had melena. The clinical examination displayed diffuse tenderness in the lower part of the abdomen.

Meckel s diverticulum probable As the transit time may not be altered, and the affected part of the intestine filled only for a short time, the invagination may be missed Observations should therefore be made at short intervals and the examination if necessary, be repeated

SUMMARY

Two cases of invagination of the small intestine produced by Meckel s diverticulum were diagnosed in adults by roentgen examination of the small intestine

ZUSAMMENFASSUNG

Zwei Falle von Dünndarminvagination der Erwachsenen wurden auf Basis des Meckelschen Divertikels bei Passageröntgenuntersuchung des Dunndarmes diagnostiziert

RÉSUMÉ

Deux cas d invagination de l intestin grele due à un diverticule de Meckel ont été diagnostiqués chez des adultes par un examen radiologique de l intestin grêle

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Roentgen examination of the small intestine with contrast medium will provide the diagnosis The prestenotic coil is dilated and the mucosal folds are smoothed out on account of the distention of the intestinal walls (18, 25) This coil also displays increased peristalsis and is raised up to form an inverted 'U' (17) Under compression it is reduced conically and symmetrically to a width of a few millimeters as it forms the canal of the intussusceptum (15, 20, 31) Without compression, the mesentery, which is drawn in between the intussuscipiens and the intussusceptum, may produce an impression in the constricting prestenotic coil, one side of which may be convex and the other concave (5) The contrast medium subsequently proceeds along the canal of the intussusceptum which, on account of the edema in the intestinal walls, is often only a few millimeters wide (18, 10) This canal has the same width throughout the entire intussusceptum (7, 20, 24, 31), and the mucous membrane is preserved with longitudinal mucosal folds owing to distension in the innermost intestinal wall of the intussusceptum (10, 16, 26, 29) No peristalsis occurs in the canal of the intussusceptum (13), which is curved and has its centre in the direction of the mesenteric root, this is on account of the distension of the mesentery that has been drawn into the invagination (15, 20, 26) After passing through the canal of the intussusceptum the contrast medium proceeds in a retrograde direction between the two outer intestinal walls and is deposited between the folds of the mucous membrane The characteristic concentric rings, with their centres on the contrast streak in the canal of the intussusceptum, are thus formed (5, 6, 7, 23, 26, 31) The contrast medium then passes on distally to the invagination

A barium enema yields no positive findings, provided the ileocaecal valve is sufficient, in cases of pure ileo ileal invagination If the contrast medium passes into the small intestine, its passage is arrested at the site of the invagination The characteristic appearances of the contrast medium coating the apex of the invagination are then observed, these were first described by LADD in 1913 If the contrast medium penetrates farther into the sheath of the intussuscipiens proximally, then a thin layer becomes apparent between the mucosal folds, and the above mentioned mucosal folds are seen (5, 7, 19, 23, 26, 31) This is characteristic of invagination but has also been described in connection with a large coprolith (2) The canal of the intussusceptum may also sometimes be filled during a barium enema examination (16 24 29)

Characteristic of both these present cases was the prolonged course the colicky pain at intervals, vomiting, constipation alternating with diarrhea, anorexia, loss of weight, and abdominal tenderness, melena occurred in both cases Such symptoms and signs should constitute an indication for examination of the small intestine

The roentgen findings were typical in both cases and established the diagnosis of ileo iliac invagination with obstruction The cause of the invagination cannot be determined at roentgen exmination, but its location distal to the ileum makes

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SOME TOMOGRAPHIC CRITERIA FOR AN EVALUATION OF THE PULMONARY CIRCULATION

by

JERZY WOJTOWICZ

A roentgenologic evaluation of the pulmonary circulation is often important in establishing the diagnosis The main pulmonary artery branches and veins may be easily examined by tomography which is used as a routine procedure in most roentgen departments An exact knowledge of the anatomy of the pulmonary vessels and ability to identify and to distinguish arteries from veins are however necessary The investigations of APPLETON (1944) BOYDEN (1955) HORNYKIEWYTSCH & STENDER (1953 1954 1955) have provided considerable information on the topography and details of the pulmonary vessels based on the segmental division of the lungs and have much facilitated the roentgenologic examination and brought it into line with clinical needs

There is still inadequate criteria for an evaluation of the width of the branches of the pulmonary artery The vascular pattern is frequently described in conventional terms and classified in routine work as decreased normal or increased and dilatation of the main branches of the pulmonary artery is sometimes evaluated by the degree of prominence of the hilar regions These arbitrary criteria are often responsible for inaccuracy in diagnosis and incorrect classification of the investigated material Many authors have on the other hand used numerical data obtained from measurements of the hilar branches

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FROM THE ROENTGEN DEPARTMENT OF POZNAN MEDICAL ACADEMY (PROF BOLESLAW GLADYSZ), POZNAN POLAND

SOME TOMOGRAPHIC CRITERIA FOR AN EVALUATION OF THE PULMONARY CIRCULATION

by

JERZY WOJTOWICZ

A roentgenologic evaluation of the pulmonary circulation is often important in establishing the diagnosis The main pulmonary artery branches and veins may be easily examined by tomography which is used as a routine procedure in most roentgen departments An exact knowledge of the anatomy of the pulmonary vessels and ability to identify and to distinguish arteries from veins are however necessary The investigations of APPLETON (1944), BOYDEN (1953) HORNYKIEWYTSCH & STENDER (1953 1954 1955) have provided considerable information on the topography and details of the pulmonary vessels based on the segmental division of the lungs and have much facilitated the roentgenologic examination and brought it into line with clinical needs

There is still inadequate criteria for an evaluation of the width of the branches of the pulmonary artery The vascular pattern is frequently described in conventional terms and classified in routine work as decreased normal or increased and dilatation of the main branches of the pulmonary artery is sometimes evaluated by the degree of prominence of the hilar regions These arbitrary criteria are often responsible for inaccuracy in diagnosis and incorrect classification of the investigated material Many authors have, on the other hand used numerical data obtained from measurements of the hilar branches

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of the pulmonary artery. These data are for several reasons insufficient for an exact evaluation, as (1) only the width of the descending part of the right pulmonary artery is given, (2) variability of the width of the pulmonary artery with age and sex is not taken into account, and (3) variations in the geometric enlargement of the vessel, produced by the roentgenographic technique, are sometimes disregarded.

The present author has attempted to define the morphologic conditions in the pulmonary circulation by means of a comparison of the width of the artery with the lumen of the associated bronchus. This relationship (diameter of the artery/diameter of the bronchus lumen), as determined in tomograms, is called the artery bronchus index or, in short, the a/b index. The idea of comparing the artery to the bronchus was suggested by ROWINSKI (1952) who observed that the lumina of the artery and bronchus were equal; this conception has however not been widely developed or introduced in practice.

The purpose of the present communication is to present a new method of evaluation of the width of branches of the pulmonary artery by means of a/b indices obtained in different regions of the pulmonary circulation, that is to say, in those of the hilar, segmental and subsegmental regions of the pulmonary artery.

Material and Methods

Roentgenograms of over 250 normal male and female patients, aged from 6 to 70 years, were studied. The roentgenologic examination consisted of conventional chest films and tomograms in frontal and sagittal planes taken in full inspiration. Tomograms in full expiration in oblique projections as well as kymograms were also sometimes obtained. Thirty morbid specimens of normal lungs and tomograms of the chest of 50 living subjects were studied in order to determine the characteristic appearances of the pulmonary branches at their points of division. The specimens were inflated to vital capacity after the injection of the pulmonary artery with contrast medium, and tomograms were obtained in different projections.

A vernier scale with an accuracy of up to 0.1 mm was used for the measurements. The outlines of the vessels and bronchi, as seen in tomograms, represent the largest cross sections and should be regarded as the true diameters, disregarding slight geometric enlargement. As arteries and bronchi may be easily measured in tomograms up to their second and third points of division, it was possible to determine the a/b indices of arteries in the subsegmental areas. The external outlines of an artery and the diameter of a lumen of a bronchus were always measured perpendicular to their long axes. The mean values of the a/b indices given in this paper are calculated to an accuracy of up to ± 0.01, for practical use however an accuracy of about ± 0.1 is sufficient.

A general rule has been that measurements of arteries and bronchi be performed exclusively on the corresponding parts of both systems, if possible at

the same distance from the nearest division of the higher order The a/b indices are determined after the segment to which the bronchus and artery belong has been defined and confirmed The identification of bronchi and vessels was based on the papers of HORNYKIEWYTSCH & STENDER, which have proved most useful

Twelve hundred tomograms were obtained in the 250 subjects examined and about 5 000 measurements were made The material was divided into four groups according to age i e 6—13 years 14—20 years 21—40 years and over 40 years as well as according to sex The values of each a/b index in these groups are given and for each group a mean arithmetic value and a standard deviation value as well The significance of the difference between the mean values for the age and sex groups was checked by statistical methods by means of the t test and the F test to the significance level of 0 05

A mean arithmetic value ($\bar{x}$) plus or minus a standard deviation value (s) taken twice are given in the tables and figures of this paper It means in effect that over 95 % of normal values should be found in the range from — 2s to + 2s around the mean value of the given index

Determination of the a/b indices

The width of the right pulmonary artery may be determined in frontal and sagittal tomograms by means of three a/b indices

1 Upper index of the pars intermedia of the right pulmonary artery The right hyparterial bronchus should be measured a few millimeters below the origin of the eparterial bronchus the pars intermedia of the right pulmonary artery being measured just below the level of the origin of the apical branches *It is often difficult* to measure the pulmonary artery at this level because the main stem often divides deep in the mediastinum furthermore arteries A2b A3a and vein V2a and its branches often mask the outline of the pars inter media

2 Lower index of the pars intermedia of the right pulmonary artery The artery should be measured just above the origin of the middle lobe arteries Both the artery and bronchus are clearly defined in tomograms and this index is the only *one that can easily* be measured in ordinary roentgenograms especially if a high kilovoltage and a stationary secondary grid are used

3 Basal index of the right pulmonary artery The bronchus and artery should be measured 0 5 to 1 0 cm above their division into branches to the basal segments of the lower lobe Since there is a wide variety of types of division at this level careful attention to the anatomical conditions is necessary

The width of the left pulmonary artery in frontal saggital and oblique projections may be expressed by two a/b indices

1 Lower index of the left pulmonary artery The artery is measured just below the origin of the lingular arteries which is usually at the same level as

Table 1

Diameter (in mm) of the pulmonary artery in different ages

Years of age	Right pulmonary artery (pars intermedia)		Left pulmonary artery (pars intermedia)	
	Males	Females	Males	Females
6–13	8.7 ± 1.2	8.4 ± 2.2	8.9 ± 2.4	9.0 ± 2.0
14–20	10.9 ± 2.6	10.5 ± 3.2	11.4 ± 3.0	11.0 ± 3.6
21–40	12.7 ± 2.6	11.5 ± 2.2	14.1 ± 3.2	11.3 ± 3.2
over 40	13.9 ± 4.2	12.0 ± 3.4	12.9 ± 3.2	11.8 ± 4.0

the origin of the artery to the apical segment of the lower lobe. The bronchus is measured at the corresponding level of the bronchial tree.

2. Basal index of the left pulmonary artery. The artery and bronchus should be measured about 0.5 to 1.0 cm above their division into basal segmental branches as in the right lung.

There are several sites where segmental and subsegmental vessels may be measured. It should be emphasized that if significant values of a/b indices are to be obtained, measurement of the corresponding artery and bronchus is required. Several segmental and subsegmental a/b indices are listed below according to their lobar association. The nomenclature used is based on the papers of HORNYKIEWYTSCH & STENDER.

I. Upper lobe: A1a/B1a, A2b/B2b, A3a/B3a, A3b/B3b and sometimes A1/B1, A3/B3.

II. Middle lobe: A4a/B4a, A4/B4, A5a/B5a, A5/B5 and sometimes Am/Bm, A5b/B5b, A4b/B4b.

III. Lower lobe: depending on the type of division, i.e. A7 + A8/B7 + B8, A9 + A10/B9 + B10 or other combinations of the segmental and subsegmental vessels.

The same a/b indices may be obtained from measurement of the bronchi and vessels in either lung, the slight differences between the right and the left lung are insignificant. About 20 a/b indices of the segmental and subsegmental vessels of the lungs were determined, and these were analysed in groups according to the lobar division of the lungs.

Influence of certain physiologic factors on the values of a/b indices. Tomograms in full inspiration are necessary for the determination of the a/b indices. Narrowing of the bronchus and slight enlargement of the vessel in full expiration may change the value of the a/b index by 0.1 to 0.2 at the hilum and by 0.3 to 0.8 at the periphery of the lung. If the lower index of the pars intermedia of the right pulmonary artery is defined in an ordinary roentgenogram, the usual exposure time of which is 0.01 to 0.1 sec, pulsations of the vessel may change the value of the index by 0.1. In tomograms, in which the exposure time is about 1 sec, pulsations of the vessel do not influence the a/b index, because

Table 2

Values of a/b indices

Sample	Lower index of right pulmonary artery	Lower index of left pulmonary artery
Males	1 24 ± 0 48	1 41 ± 0 34
Females	1 24 ± 0 28	1 40 ± 0 28
6–13 yrs	1 28 ± 0 48	1 42 ± 0 34
14–20 yrs	1 25 ± 0 40	1 42 ± 0 28
21–40 yrs	1 27 ± 0 32	1 39 ± 0 42
Over 40 yrs	1 22 ± 0 28	1 38 ± 0 44

the largest diameter of the vessel is always seen The lower index of the right pulmonary artery may be determined in most cases in ordinary films although the measurements are less accurate The outlines of the bronchus and vessel are often unsharp pulsations may change the width of the latter and there is always considerable difficulty properly to identify both stuctures These factors may all cause inaccurate measurements

It should always be remembered that there are two parameters forming an a/b index the diameter of the artery and the diameter of the lumen of the bronchus Certain constant conditions in the bronchial tree are required if morphologic equivalents of the hemodynamic changes are to be properly expressed in a/b indices The tomograms should be taken in full inspiration The a/b indices should not be determined if pathologic changes such as bronchiectases or narrowing of the bronchi are found Oedema of the wall of the bronchus which often occurs in mitral disease, may also change the value of the a/b index An approximate value may be obtained in these cases if allowance is made for the thickening of the wall

Dependency of the a/b indices on age and sex Diameters of the right and left pulmonary artery for the age and sex groups are given in Table 1 The right pulmonary artery was measured just above the origin of the middle lobe arteries the left pulmonary artery being measured at the level of the origin of the artery to the apical segment of the left lower lobe Corrections have been made for geometric enlargements of the vessels in all the data It is evident that the diameters of both arteries increase with age particularly in the first two decades of life and are larger in males within the given age group From the practical point of view the numerical data obtained from measurements of these arteries are of limited value since they were obtained only for two segments Moreover there is a significant variability with age sex and body build The necessity of introduction of corrections for geometric enlargement of vessels may be regarded as another disadvantage

The widths of the right and left pulmonary artery expressed in the values of a/b indices are given in Table 2 Statistical analysis of these data revealed

Table 3

Values of a/b indices and mean arithmetic values

	Mean arithmetic value ± standard deviation value taken twice
Right pulmonary artery	
Upper index	1 03 ± 0 34
Lower index	1 24 ± 0 44
Basal index	1 31 ± 0 42
Left pulmonary artery	
Lower index	1 40 ± 0 28
Basal index	1 32 ± 0 34
Segmental and subsegmental arteries of	
Right upper lobe	1 18 ± 0 40
Right middle lobe	1 16 ± 0 40
Right lower lobe	1 19 ± 0 20
Left upper lobe	1 18 ± 0 32
Lingula	1 20 ± 0 34
Left lower lobe	1 22 ± 0 44

that the values of the a/b indices are independent of age and sex Some slight differences between the mean values in the age and sex groups for the given a/b index are statistically insignificant As far as the other a/b indices are concerned, it has been proved statistically that they are independent of age and sex

Normal mean values of a/b indices are given in Table 3 and Fig 1 All the data were calculated from measurements in tomograms taken in full inspiration with the subject in the supine position

Divisions of the pulmonary artery branches and some relationships between the main stem and branch diameters Over twelve hundred divisions were analysed in tomograms of morbid specimens, and in tomograms of normal subjects, in order to evaluate the types of division of the branches of the pulmonary artery The diameter of the main artery was measured just above its division into secondary branches, the diameters of the branches being obtained just below the level of the division The angle of division was measured between the long axis of the stem and the long axis of the branch In this way branches of both the pars intermedia of the pulmonary artery and the segmental and subsegmental arteries and sometimes their branches were measured

It has been found that there are two morphologic types of division of the pulmonary artery bifurcation and collateral branching (Fig 2) Each of these types has certain characteristic features

Bifurcation This form is characterized by the division of the main artery into two branches of almost equal size, in most cases (72 %) the angle of division

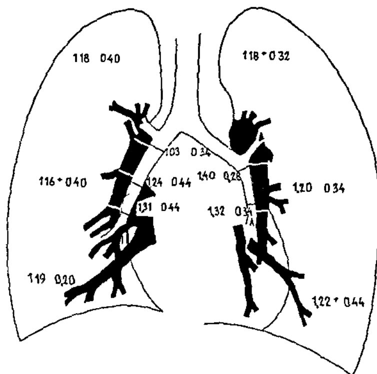


Fig 1 Normal mean values of the a/b indices

of each branch being between 10 and 30 (Fig 3) and the sum of the angles of both branches in most cases (64 %) lying in the range of 30 to 60 The diameter of one of the branches is larger than half the main stem diameter in 91 % of cases and the sum of the diameters of both branches is generally greater than the stem diameter

Collateral branching The main stem in this type of division divides into a branch that is almost as large as the stem and runs in the same direction and a smaller branch (Fig 2) The angle of division in 77 % of cases is from 30° to 80 (Fig 3) The relationship between the main stem and branch diameter is characteristic i e in 70 % of cases the diameter of the branch is smaller than half the stem diameter It was found as in the bifurcation type that the sum of the diameters of the branches is always greater than the stem diameter

These criteria are obviously simplified, as they must be if a three dimensional structure is analysed in a two dimensional tomogram Since there is a wide range of normal values of angles of division the data given seems to have limited practical value although the extremes may be helpful in suggesting pathosis There is however one criterium that would appear to be of some

Table 3

Values of a/b indices and mean arithmetic values

	Mean arithmetic value ± standard deviation value taken twice
Right pulmonary artery	
Upper index	1.03 ± 0.34
Lower index	1.24 ± 0.44
Basal index	1.31 ± 0.4[illegible]
Left pulmonary artery	
Lower index	1.40 ± 0.28
Basal index	1.32 ± 0.34
Segmental and subsegmental arteries of	
Right upper lobe	1.18 ± 0.40
Right middle lobe	1.16 ± 0.40
Right lower lobe	1.19 ± 0.20
Left upper lobe	1.18 ± 0.32
Lingula	1.20 ± 0.34
Left lower lobe	1.22 ± 0.44

that the values of the a/b indices are independent of age and sex. Some slight differences between the mean values in the age and sex groups for the given a/b index are statistically insignificant. As far as the other a/b indices are concerned, it has been proved statistically that they are independent of age and sex.

Normal mean values of a/b indices are given in Table 3 and Fig. 1. All the data were calculated from measurements in tomograms taken in full inspiration with the subject in the supine position.

Divisions of the pulmonary artery branches and some relationships between the main stem and branch diameters. Over twelve hundred divisions were analysed in tomograms of morbid specimens, and in tomograms of normal subjects, in order to evaluate the types of division of the branches of the pulmonary artery. The diameter of the main artery was measured just above its division into secondary branches, the diameters of the branches being obtained just below the level of the division. The angle of division was measured between the long axis of the stem and the long axis of the branch. In this way branches of both the pars intermedia of the pulmonary artery and the segmental and subsegmental arteries and sometimes their branches were measured.

It has been found that there are two morphologic types of division of the pulmonary artery: bifurcation and collateral branching (Fig. 2). Each of these types has certain characteristic features.

Bifurcation. This form is characterized by the division of the main artery into two branches of almost equal size, in most cases (72 %) the angle of division

It is known that an evaluation of the pulmonary circulation based on ordinary films and expressed in conventional terms may often be misleading and cardioangiography is not always possible or indicated The present writer has reported elsewhere (WÓJTOWICZ (1963) that disturbances in the pressure and flow in the pulmonary circulation within the range in which they change the morphologic conditions in the pulmonary artery may easily be expressed by means of a/b indices These indices seem to be more accurate and more convenient than other methods of evaluation of the pulmonary vascular pattern in cases of chronic cor pulmonale mitral disease and congenital malformations of the heart and vessels

Conclusions

1 The artery/bronchus indices determined in tomograms may express morphologic conditions in the pulmonary artery

2 The range of evaluation is somewhat increased i e the width of the both pulmonary arteries at the hila and some segmental and subsegmental vessels may be evaluated

3 The values of the a/b indices are independent of age sex and type of body build

4 Since an a/b index is a relative value geometric enlargements under different technical conditions may be disregarded

5 Two types of division of the pulmonary artery branches were found, i e bifurcation and collateral branching Each has certain characteristic morphologic features that may be of value in the diagnosis of pulmonary artery pathosis

SUMMARY

A method of evaluation of the branches of the pulmonary artery by means of an artery/bronchus index is proposed The mean values of the indices for the main segmental and subsegmental pulmonary arteries based on 1 200 tomograms of 250 normal subjects are given The value of th indices are independent of age sex body build and geometrical condition

ZUSAMMENFASSUNG

Eine Methode zur Abschatzung der Aste der Pulmonalarterie mittels eines Arterien Bronchus Quotienten wird vorgeschlagen Die Mittelwerte dieses Quotienten fur Haupt stamme und fur die segmentaren und subsegmentaren Arterien wurden an 1 200 Tomogrammen von 250 normalen Individuen ermittelt Der Wert des Quotienten ist unabhangig von Alter Geschlecht Korperbau oder geometrischen Einflussen

RÉSUMÉ

L auteur propose une méthode pour apprécier l état des branches de l artere pulmonaire au moyen d un indice artère/bronche Il donne les valeurs moyennes des indices pour les artères pulmonaires principales segmentaires et sous segmentaires d après 1 200 tomographies de 250 sujets normaux Les valeurs de ces indices sont indépendantes de l age du sexe du type corporel et des facteurs géométriques

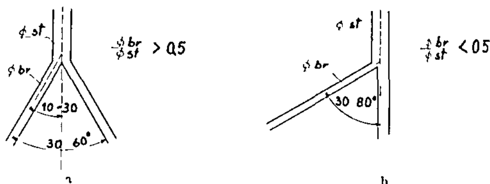


Fig 2 Types of division of the pulmonary artery branches O st denotes stem diameter O br denotes branch diameter a) Bifurcation type b) Collateral branching type

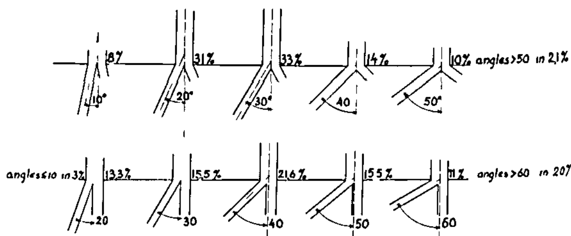


Fig 3 Distribution in per cent of the angles of division in the bifurcation type (upper part of diagram) and in the collateral branching type (lower part of diagram)

value in the evaluation of the caliber of the pulmonary artery at the division site This is the constant relationship of the main stem diameter to the diameters of the branches, i e the sum of the diameters of the branches is always greater than the diameter of the stem

Independency of age and sex is an important advantage in the evaluation of the utility of a/b indices in the definition of morphologic conditions in the branches of the pulmonary artery While an a/b index does not change with age and sex, the diameter of the equivalent artery is largely dependent on age, sex, and body build Moreover, a/b indices may be determined not only of the main artery but also of the segmental and subsegmental vessels, which somewhat increases the range within which an evaluation may be obtained The fact that the a/b index does not depend upon the geometrical conditions under which the tomograms are taken may be considered another advantage of this method

It is known that an evaluation of the pulmonary circulation based on ordinary films and expressed in conventional terms may often be misleading and cardio angiography is not always possible or indicated. The present writer has reported elsewhere (Wojtowicz (1963) that disturbances in the pressure and flow in the pulmonary circulation, within the range in which they change the morphologic conditions in the pulmonary artery may easily be expressed by means of a/b indices. These indices seem to be more accurate and more convenient than other methods of evaluation of the pulmonary vascular pattern in cases of chronic cor pulmonale, mitral disease and congenital malformations of the heart and vessels.

Conclusions

1. The artery/bronchus indices determined in tomograms may express morphologic conditions in the pulmonary artery.

2. The range of evaluation is somewhat increased, i.e. the width of the both pulmonary arteries at the hila and some segmental and subsegmental vessels may be evaluated.

3. The values of the a/b indices are independent of age, sex and type of body build.

4. Since an a/b index is a relative value, geometric enlargements under different technical conditions may be disregarded.

5. Two types of division of the pulmonary artery branches were found, i.e. bifurcation and collateral branching. Each has certain characteristic morphologic features that may be of value in the diagnosis of pulmonary artery pathosis.

SUMMARY

A method of evaluation of the branches of the pulmonary artery by means of an artery/bronchus index is proposed. The mean values of the indices for the main, segmental and subsegmental pulmonary arteries based on 1200 tomograms of 250 normal subjects are given. The value of the indices are independent of age, sex, body build and geometrical conditions.

ZUSAMMENFASSUNG

Eine Methode zur Abschatzung der Äste der Pulmonalarterie mittels eines Arterien Bronchus Quotienten wird vorgeschlagen. Die Mittelwerte dieses Quotienten fur Hauptstamme und fur die segmentaren und subsegmentaren Arterien wurden an 1 200 Tomogrammen von 250 normalen Individuen ermittelt. Der Wert des Quotienten ist unabhangig von Alter, Geschlecht, Korperbau oder geometrischen Einflussen.

RÉSUMÉ

L'auteur propose une méthode pour apprécier l'état des branches de l'artère pulmonaire au moyen d'un indice artère/bronche. Il donne les valeurs moyennes des indices pour les artères pulmonaires principales, segmentaires et sous segmentaires d'après 1 200 tomographies de 250 sujets normaux. Les valeurs de ces indices sont indépendantes de l'âge, du sexe, du type corporel et des facteurs géométriques.

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ROENTGENOLOGIC AND MORPHOLOGIC STUDIES OF THE MUCOUS MEMBRANE MOVEMENTS IN THE STOMACH OF THE CAT

A preliminary report

by

TORGNY GREITZ

The mechanism of the folds of the gastrointestinal tract is still not completely understood in spite of the great number of publications on the subject. FORSSELL (1913) was the first to point out the significance of the smooth muscles in the mucous membrane and presumed that the lamina muscularis mucosae was of far greater importance than the outer muscle wall, the tunica muscularis. In his later works he considered that variations in the degree of filling of the vessels and in the distribution of fluid in the submucosa also played a certain role. Such changes were, however, impossible to demonstrate with the fixation methods that he had at his disposal. SJÖSTRAND (1942), in animal experiments using freeze drying fixation following freezing in liquid air, was able to confirm FORSSELL's assumptions and showed that the blood and the lymphatic vessels of the submucosa were collected in the folds of the mucous membrane and that the lymphatic vessels were dilated within the folds but collapsed in between them; in addition the connective tissue in the folds was infiltrated with fluid.

Several authors have reported roentgenologic investigations on the functional

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variations of the mucous membrane in animals and man, before and after administration of drugs influencing the autonomous nervous system. Only one or a few cases were usually examined and no uniform, reproducible changes after specific stimuli of the gastric mucosa were demonstrated. WILDE (1934) claimed, however, to have found 'gewisse Gesetzmässigkeiten im Verhalten der Magenschleimhaut' following administration of drugs. The mucosal folds appeared to be broader and more sinuous after the injection of adrenaline or histamine but broader, more numerous and more tortuous after the injection of pilocarpine. According to TESCHENDORF, ephedrine resulted in broader folds which sometimes became straighter and sometimes more tortuous than before the injection. ÖTVÖS (1952) found that the mucosal relief, after an initial period of decreased or increased folding, became smoother with smaller folds following the injection of atropine. Tetraethylammonium bromide is a ganglion blocking agent which, according to PORCHER (1952), causes the normal rugae to stand out more clearly. GRETTVE (1936) examined the exposed mucous membrane of the cat's stomach and demonstrated certain reproducible changes after the application of drugs. Adrenaline caused reduced tonus and at the same time increased folding of the mucous membrane with thin, high folds, pilocarpine caused increased tonus and a flattening of the rugae. GRETTVE also found that histamine produced a thickening of the mucosal folds. Several authors, e. g. ALBOT (1952), JULIANI & SANNAZZARI (1956) and PFEIFFER (1957) have been interested in what they call 'pharmacoradiography'. These authors studied mainly the motility of the stomach and intestine or the use of drugs for roentgendiagnostic purposes but were not specifically interested in the pattern of the mucous membrane.

It is apparent that many problems associated with the physiology and pathology of the mechanism of folding remain unsolved. The importance of the different components of the gastric wall for the formation of rugae are to a large extent still unknown, and no definite knowledge has been obtained about the autonomic mechanisms that govern this process. An attempt has therefore been made to examine the variations of the gastric mucosal relief and their morphologic basis by a combined roentgenologic and histologic study in which the mucous membrane of the cat has been influenced by autonomotropic drugs and then fixed by the freeze drying method.

Material and Methods. The experiments were performed in 23 cats weighing 1.9 to 3.3 kg anesthetized with 40 to 70 mg per kg body weight dial injected intravenously. The esophagus was ligated to avoid volume changes in the stomach due to swallowed air, and 3 to 7 ml of a thick suspension of barium sulphate in water were administered through an esophageal catheter. Drugs were administered intravenously and their effect was checked radiologically with up to 20 exposures at 1 to 10 min intervals with the animal on its back and the projection unchanged.



Fig 1 Injection of 0.5 mg/kg bodyweight adrenaline a) Immediately before injection b) 5 min later The stomach is dilated and several new narrow folds have arisen especially within the antrum

The abdominal cavity was opened in 11 experiments when maximum effect on the mucous membrane was reached The esophagus and the duodenum were divided between clamps and the stomach was quickly usually within a minute removed in one piece and immediately fixed in liquid air or liquid nitrogen The appearances of the specimen were checked roentgenologically, and portions of the stomach wall were then removed with a chisel and dried in vacuo in an ordinary freeze dryer After fixation the specimen was transferred in celloidin via pure alcohol cut in serial sections and stained with haematoxylineosin

The mucous membrane relief was varied experimentally after injection of autonomotropic drugs Experiments were made with a sympathicommeticum (adrenaline 0 1 to 0 5 mg/kg) with a sympathicolyticum (gynergen 0 2 mg/kg) with two different parasympathicomimetica (pilocarpine and tikaryl or carbamylmethylcholine chloride 0 5 mg/kg) with a parasympathicolyticum (atropine 0 05 to 1 mg/kg) with a ganglion blocking agent (etamon or tetraethyl ammonium bromide 25 mg/kg) and with histamine (0 1 to 1 0 mg/kg) Several of the above mentioned drugs were tried one after the other during 12 preliminary experiments that were not followed by fixation

Results

A Roentgenologic observations

Spontaneous variations of the shape and size of the stomach and of the appearance of the mucous membrane occurred during dial anesthesia These changes were however only small The volume of the stomach was estimated

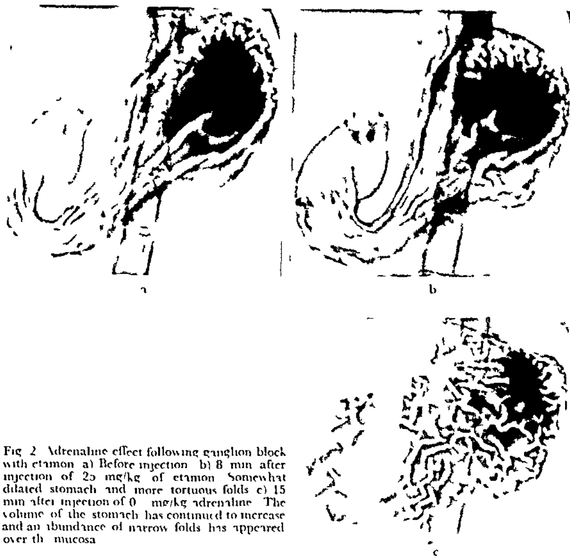


Fig 2 Adrenaline effect following ganglion block with etamon a) Before injection b) 8 min after injection of 25 mg/kg of etamon Somewhat dilated stomach and more tortuous folds c) 15 min after injection of 0 [illegible] mg/kg adrenaline The volume of the stomach has continued to increase and an abundance of narrow folds has appeared over the mucosa

only in the frontal projection in these preliminary experiments It was noted that the mucous membrane relief could change and then recover its earlier appearances, which suggested a certain preformation The changes described below were either very marked or, when that was not the case, in repeated experiments always appeared in connection with the injection

1 Sympathicomimeticum Adrenaline had either no effect on the shape or size of the stomach or caused a slight dilatation In spite of this the folding in the mucous membrane of the stomach increased The surface of the mucous membrane therefore increased more than the remainder of the stomach wall, the folds became higher and thinner and also more numerous (Fig 1) This effect reached its maximum as early as 3 to 5 minutes Adrenaline was injected in one

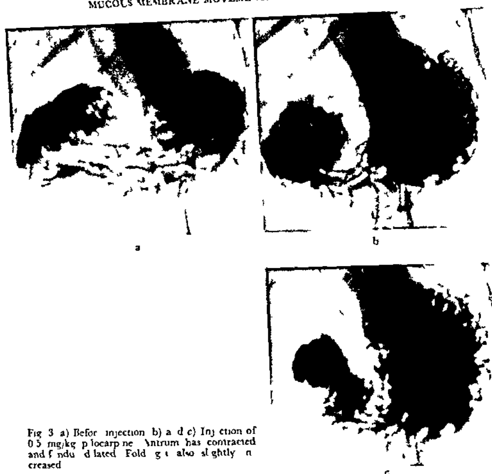


Fig 3 a) Before injection b) and c) Injection of 0.5 mg/kg pilocarpine Antrum has contracted and fundus dilated Folding is also slightly increased

experiment after a ganglion blocking agent (etamon) had been used The same changes as were observed following adrenaline injection alone were obtained but they were apparently increased (Fig 2) The etamon injection per se caused a moderate dilatation of the stomach increased convolution of the folds and a certain formation of new folds in the mucous membrane

2 *Parasympathicomimeticum* Pilocarpine (and tikaryl) caused a characteristic change in the shape of the stomach identical with that described after stimulation of the vagus nerve (KLEE 1914) i e the antrum became contracted, the fundus dilated and the stomach assumed a more rounded shape (Fig 3) At the same time the mucous membrane folds became more numerous and more irregular

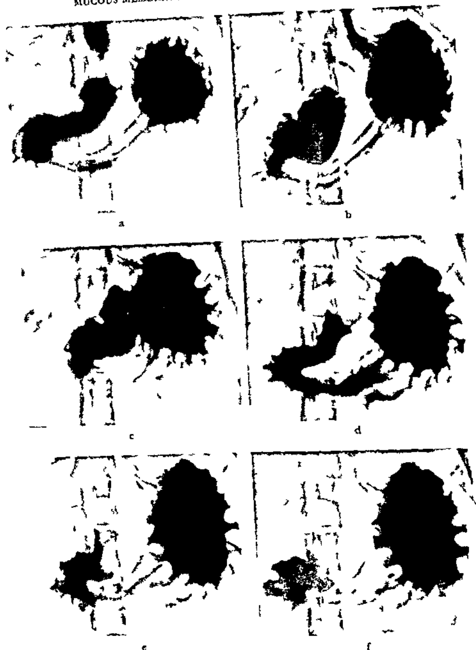


Fig 4 a) Before injection b) 10 min after injection of 0.2 mg/kg histamine Mucosal folds have become broader and are longitudinally arranged

3 *Sympathicolyticum* The effect of gynergen on the shape of the stomach and on the mucosal relief seemed to be similar to the parasympathomimetic effect, but the influence on the outer shape was less marked than that following the injection of pilocarpine

4 *Parasympathicolyticum* It is generally considered that atropine injected into a human being reduces the tonus of the stomach and decreases the folding of the mucous membrane The writer has not been able to observe such an effect on the appearances of the relief in 11 different experiments in cats, in 8 of these no apparent change was observed (Fig 5) and in 3 experiments the atropine injection resulted in a slight widening of the stomach and a certain thickening of the mucosal folds (Fig 6)

5 *Histamine* injections provoked thick broad folds, which stood close to each other and had a characteristic longitudinal arrangement, especially marked in the corpus part, which was dilated (Fig 4) The histamine effect was obviously accentuated if atropine was previously administered (Figs 5 and 6) When histamine was injected into human subjects a similar change in the appearances of the mucous membrane, with broad folds running in the longitudinal direction of the stomach, was obtained These changes seemed, in accordance with the animal experiments, to be more marked after a preceding atropine injection



F g 5 Effect of h tam ne f llow ng atrop ne injection a) Befo e njection b) 60 m n after in j ct on of 0 ? mg kg atrop ne No obv ous change in the mucosal rel ef c) 1 min afte (b) and after i jection f 0 2 mg kg hi tamine d) e) and f) At 5 15 and 25 min after injection of histam ne Typ cal but acce tuated cha ges due to histami e act on



Fig 6 Atropine and histamine effects a) Before injection b) 30 min after injection of 1 mg/kg atropine Increased folding and slight dilatation of stomach c) 20 min after injection of 1 mg/kg histamine

B Morphologic observations

In the 11 cases in which freeze drying fixation was used the specimen containing barium was checked roentgenographically immediately after freezing Changes in the shape and size of the stomach as well as of the mucosal pattern were observed in every case following the fixation procedure These changes made identification of individual folds impossible However, the mucous membrane kept its general characteristic appearances broad folds in the relief could be observed after fixation if such folds were to be found before

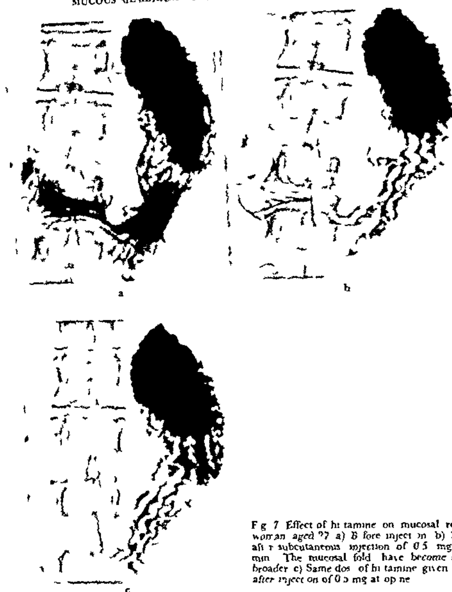


Fig 7 Effect of histamine on mucosal relief in woman aged ?7 a) Before injection b) 30 min after subcutaneous injection of 0 5 mg histamin The mucosal fold have become slightly broader c) Same dose of histamine given 40 min after injection of 0 5 mg atropine

So far only the effect of atropine and histamine per se and of histamine after a preceding injection of atropine has been studied The general histologic appearance of the folds in the specimens examined to date corresponded to the description given by SJOSTRAND There was consequently a concentration of blood vessels and dilated lymphatic vessels in the submucosa within the folds

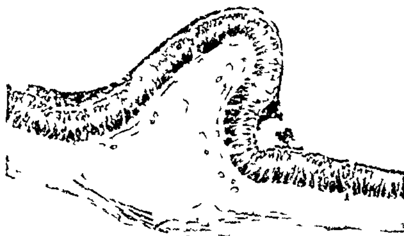


Fig. 8. A mucosal fold from stomach of a cat given 0.3 mg/kg atropine. An abundance of dilated lymphatic vessels present in the submucosa within the fold. Freeze dry fixation, haematoxylin-eosin.

The lymphatic vessels were collapsed between the folds, and there was an infiltration of fluid in the connective tissue, especially at the bases as well as at the edges of the folds.

An abundance of dilated lymphatic vessels was evident in the submucosa, especially in the folds of the stomach wall of an animal that reacted after atropine injection with an increase in the width of the mucousal folds (Fig. 8). Many dilated thin walled blood vessels were found in the mucosal folds of those cats given histamine (Fig. 9).

Discussion and Conclusions

The experiments carried out up to now show that the appearances of the gastric mucous membrane of the cat may be varied experimentally by injecting drugs that influence the autonomic nervous system. The changes in the width of the mucosal folds, which were observed roentgenologically after injections of adrenaline and histamine, agree with GRETTVE's observations following direct application of the drugs on the exposed gastric mucosa of the cat.

The present findings of the effect of the injection of pilocarpine are however not in agreement with GRETTVE's observations as he found this drug to cause a flattening and a smoothing of the folds. These discrepancies in the observations of the effects of pilocarpine may be explained by GRETTVE's working with fixed tunica muscularis, which prevents its influence on the mucous membrane relief. As the mucosal changes are recorded at the same time as an obvious alteration in the outer shape of the stomach, it is probable that the folding observed after the injection of parasympathicomimetica depends partly on contractions of the tunica muscularis.



Fig 9 Appearance of mucosal fold following injection of 0 2 mg/kg histamine Several thin walled dilated blood vessels are evident mainly within the broad fold, suggesting hyperemia Hyperemic changes are also present in the serosa

The increased mucosal folding noted after the injection of adrenaline cannot be due to the action of the tunica muscularis as the volume of the stomach remains unchanged or becomes slightly larger The change in appearance of the folds may be explained as a result of the adaptation of the enlarged mucous membrane in the unchanged or relatively unchanged space, which is surrounded by the remainder of the stomach wall The mucous membrane increases its surface and pushes itself towards the base of the folds which thereby become thinner and into the folds which therefore also become higher in addition new folds are formed between the old ones

The broadening of the mucosal folds observed as a result of the injection of histamine and in certain cases of atropine is difficult to explain on a similar simple mechanical basis The morphologic observations made in such cases support the assumption that alterations in the blood and lymphatic vessels constitute an additional factor in the formation of mucosal folds

The doses used are very large and partly toxic The roentgenologically observed changes are however qualitatively different By comparing these changes with morphologic data from a greater material a further step may be taken towards an increased understanding of the folding mechanism of the gastric

mucosa and the factors that control it. Due to the fact that changes in the mucosal relief can be provoked, experimental possibilities of studying the creation of new folds are afforded. The greatest chance of recording changes in the muscles of a newly formed fold ought to be found exactly in the early phase of folding. One pre-requisite for determining the age of a fold is, however, that it can be indentified after fixation. Fixation in situ is therefore necessary. This however, offers great difficulties due to the large size of the experimental animals, but should be done in future investigations. It should not be impossible, judging by preliminary experiments, to reproduce the changes observed in human beings.

Acknowledgements

The author is indebted to Fritiof Sjostrand, upon whose suggestion the investigation was undertaken, for his advice and encouragement. Bengt Fredriksson gave valuable assistance and instructions in the use of the method of freeze drying fixation.

SUMMARY

A preliminary combined roentgenologic and histologic study of the movements of the gastric mucosa in cats is reported. Qualitatively different changes could be provoked by the injection of autonomotropic drugs. These alterations were checked by serial roentgenography and in some cases histologically after fixation by the freeze drying method.

ZUSAMMENFASSUNG

Die Arbeit ist ein vorläufiger Bericht über kombinierte röntgenologische und histologische Untersuchungen der Beweglichkeit der Magenschleimhaut der Katze. Durch Injektion von Substanzen, die das autonome Nervensystem beeinflussen, konnten qualitativ verschiedene Wirkungen hervorgerufen werden. Die Veränderungen wurden an Serienröntgenaufnahmen festgestellt und histologisch mittels Gefriertrocknung überprüft.

RÉSUMÉ

L'auteur présente une étude préliminaire radiologique et histologique des mouvements de la muqueuse gastrique du chat. Il a pu provoquer des modifications qualitativement differentes par l'injection d'agents autonomotropes. Ces altérations ont été controlées par la radiographie en séries et dans certains cas histologiquement après fixation par la méthode de dessication par congélation.

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BRONCHOGRAPHY WITH AN ÖDMAN CATHETER

by

PEKKA VIRTAMA

Bronchography may be performed by several methods. Oily contrast media may be instilled through a catheter into the epiglottic space and actively inspired by the patient, or percutaneous cricothyroid puncture with injection of contrast media may be performed (HELMSLEY et coll. 1961, ZUCKERMAN & JACOBSON 1962, STUTZ & VIETEN 1955). An active inspiration method often results in fairly good outlining of the bronchial tree, but may otherwise leave much to be desired. It is probable that the introduction of a catheter into the trachea, or into one of its main branches, still gives the most satisfactory filling of the bronchial tree although to the roentgenologist of limited experience in laryngoscopy the passing of a catheter into the trachea is generally difficult and time consuming.

The well known principles of selective arterial catheterization may easily be adapted to bronchography. The special advantage of this method is the easy introduction of the small catheter into the trachea without laryngoscopy. The technique is as follows.

After premedication and local anesthesia of the larynx with 3 to 5 ml xylocaine 5 % spray, a special throat spatula, to which an Ödman catheter with Seldinger wire is attached, is placed on the superior surface of the tongue. Figs 1

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Fig 1



Fig 2

Fig 1 The throat spatula made of perspex with an Ödman catheter inserted Dimensions of the spatula are 0 9 × 2 0 × 21 0 cm and its distal end is rounded

Fig 2 The proximal end of the spatula with a teflon catheter of inner diameter of 3 mm embedded in its upper part and with an Ödman catheter inserted



Fig 3 The left bronchial tree as seen by means of an Ödman catheter introduced into the left main bronchus

and 2) with the patient sitting or in the lateral decubitus position. The passage of the tip of the catheter is controlled by fluoroscopy, the field size being restricted to 5 × 5 cm. The use of an image amplifier and television screen is naturally an advantage. The catheter is introduced into the trachea by slightly moving the proximal end of the spatula, which then is removed, and 2 ml xylocaine are injected through the former. The Seldinger wire is then reinserted and the tip of the catheter is introduced into the bronchial branch to be examined. The shape of the catheter tip may be selected to suit the angle of the particular bronchus, a straight catheter is satisfactory for the trachea and its main branches. Side holes may also be used so as to facilitate the flow of the contrast medium (Dionosil Aqueous — Glaxo Laboratories Ltd), which is injected into the catheter with an ordinary 2 ml syringe fitted with a needle. Fairly good filling of the entire bronchial tree may be obtained with 5 ml of the contrast medium with the catheter lying in the main bronchus (Fig. 3).

The method of introducing the catheter into the trachea is similar to that earlier described by EPSTEIN (1961). The small diameter of the catheter in the present method makes the procedure more pleasant for the patient and also facilitates the introduction of the catheter into the desired position.

SUMMARY

A method of bronchography by means of an Ödman catheter introduced into the trachea with the aid of a special throat spatula is described.

ZUSAMMENFASSUNG

Die Verwendung des Ödman Katheters, der mit Hilfe eines besonders konstruierten Spatels in die Trachea eingeführt wird, wird als eine neue bronchographische Methode beschrieben.

RÉSUMÉ

Description d'une méthode de bronchographie au moyen d'un cathéter d'Ödman introduit dans la trachée grâce à une spatule laryngée spéciale.

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RISKS IN SELECTIVE RENAL CATHETERIZATION AND ARTERIOGRAPHY

An experimental study in dogs

by

N P G EDLING and C O OVENFORS

EDLING et coll (1958 1959) in previous experimental studies in dogs demonstrated the risks of injury to the kidneys in renal aortography as well as in selective renal catheterization and arteriography The examinations were performed by catheterization of the femoral arteries and di and three iodine compounds were used as contrast media The results of the previous experiments suggested that aortography in human subjects with normal kidneys should not cause renal damage while selective arteriography might do so As selective renal arteriography would appear to be diagnostically superior to renal aortography the risks associated with the catheterization and arteriography of the renal arteries will be considered once again in the present experimental study in dogs

The dogs were kept under superficial general anesthesia, 0 5 to 0 7 ml/kg bodyweight pentothal sodium Abbot (thiomebumal sodium) 5 % plus 0 10 to 0 12 ml/kg bodyweight nembutal Abbot (pentobarbitone sodium) 6 %

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were given for induction and 1 to 2 ml pentothal sodium for maintenance when necessary The media were injected intravenously in a hindleg

The catheterizations were performed percutaneously in both femoral arteries by the Seldinger method Red or yellow Ödman catheters were introduced into the renal arteries via the aorta during fluoroscopy with an image intensifier The catheters were repeatedly flushed with normal saline with 3 drops of added heparin solution 5 000 IU/100 ml in order to obviate clot formation

One millilitre/kg bodyweight Urografin (sodium methylglucamine diatrizoate) 15 % was injected in the aorta at the level of the second lumbar vertebra for initial localization of the origins and courses of the renal arteries and films were obtained Renal aortography was then performed after a further injection of 1 ml/kg bodyweight Urografin 30 % or 45 % for an initial study of the condition of the kidneys The proximal parts of the renal arteries were catheterized at that stage The subsequent experiments were divided into three separate groups

First group The tips of the catheters were kept in the proximal parts of the arteries and 1 5 ml/kg bodyweight Urografin 4 6 % injected on one side, simultaneously with an equal dose of plasma isosmotic sodium iodide 2 3 % on the other side The selective injections were repeated in each dog with the sides changed The arterial blood pressure of the dogs was lowered to about 30 mm Hg when the injections started, this was accomplished by increasing the intrabronchial pressure by means of an oxygen injector (NORDENSTRÖM 1960) connected to the intubated dog As soon as the contrast medium injections were completed the blood pressure was restored to a normal level and a final renal aortography was performed

Second group The catheters were placed distally in the renal arteries for periods ranging from 5 to 9 minutes but no contrast medium was injected The catheters were then withdrawn into the aorta, and renal aortography was performed for the study of the condition of the kidneys after the obstruction The efficiency of the obstruction of the renal arteries by the catheters was checked in a few dogs by means of a third catheter through which renal aortography was carried out (Fig 1)

Third group The position of the catheters in the renal arteries was the same as in the second group and was maintained for periods ranging from 3 to 7 minutes, 0 1 to 0 25 (in one kidney 0 42) ml/kg bodyweight Urografin 30 % was then injected before the catheters were withdrawn into the aorta Renal aortography was then in some animals carried out

The contrast medium injections, in the renal aortographies, were performed with the Gidlund injection syringe and the injection time was about 4 seconds The selective injections were carried out manually at moderate speed The



Fig 1 Bilateral selective renal catheterization (right yellow Ödman catheter left red Ödman catheter) as far distally as possible and aortography by means of a third catheter Good filling of the branches of the renal arteries Very small infarctions in the right and a large infarction in the left kidney with mineral salt deposits were evident histologically

timing of the aortograms, in which a Gidlund automatic film changer (Elema) with roll film was used was one every second for two seconds one every two seconds for ten seconds and one every ten seconds for fifty seconds Most of the selective renal arteriograms were also recorded on roll film for which the timing of the exposures was one every two seconds for twelve seconds and one every ten seconds for sixty seconds A few examinations were performed with a series of cut films Single films in addition to the above were also obtained at 2 3 and 4 minutes after the start of the injection

A study of the angionephrographic effect was used as the only test of renal function in the present series of the experiments

The dogs were kept alive after the experiments for periods ranging from 3 days to 8 weeks during which time they behaved in a normal way Further renal aortographies were performed in some dogs The dogs were killed by desanguination and the kidneys removed immediately, these were then divided into two fixed in 10 % formalin solution and prepared for microsropic examination

Material

The examinations were performed in 18 healthy dogs about two to three years of age, and of weights ranging from 19 to 25 kg Thirty three of the 36 kidneys were catheterized, in two dogs in which two right renal arteries existed, the upper were catheterized

The *first group* with selective catheterization of the proximal parts of the renal arteries and contrast medium injections during reduced arterial blood pressure consisted of 5 dogs and 10 kidneys

The *second group* with catheterization of the renal arteries as far distally as possible consisted of 8 dogs and 14 kidneys Selective catheterization of the artery failed in the two remaining kidneys The degree of obstruction of the renal arteries by the indwelling catheters was tested in four dogs and seven kidneys (by means of renal aortography via a third catheter) One dog of this group had also been subjected to the experiment of the first group

The *third group*, with catheterization of the renal arteries as far distally as possible combined with contrast medium injections, consisted of 5 dogs and 8 kidneys Obstruction by the catheter in the ninth kidney was not followed by contrast medium injection, and the remaining kidney was not examined

Results

The angionephrographic effect ran a normal course in both kidneys in all the initial renal aortographies and contrast filling of the pelves and ureters occurred normally

In the *first group* with selective catheterization and simultaneous injections *of diatrizoate in one and sodium iodide in the other renal artery during reduced* arterial blood pressure, the angionephrographic effect appeared normal in all kidneys The degree of density of both kidneys was equal during the course of the phenomenon (EDLING & OVENFORS 1962) and the angionephrographic effect also appeared normal in the final renal aortographies

The dogs were killed after intervals ranging from 3 days to 6 weeks, and histologic examination of the 10 kidneys was performed Slight pyelonephritic changes of a type frequently seen in dogs were evident in 2 kidneys and are of no significance in the present study Six of the kidneys had areas of nephron destruction with definite changes in the tubules and slight changes *in* the glomeruli Fibrotic changes were evident in kidneys that were removed relatively late following the experiments, 5 of them also had mineral salt deposits, which both in the tubules and interstitially dyed as lime, and were present as early as 1 to 3 weeks after the experiment The changes had the character of wedge shaped infarctions extending from the medulla into the cortex and were marked in 3 kidneys and moderate or slight in the remaining 3 The mineral salt deposits were considerable in 4 of them The infarctions in 4 of the kidneys were evident macroscopically as pale areas

In the *second group* with selective catheterization of the renal arteries as far distally as possible renal aortography with the catheters within the renal arteries and after their withdrawal revealed good arterial filling and a normal angionephrographic effect This finding indicates that the obstruction caused by the catheters selectively introduced was incomplete (cf Fig 1)

The dogs were killed after intervals ranging from 4 to 8 weeks The histologic examinations of the 16 kidneys revealed that 6 had slight pyelonephritic changes of the common type and 7 had infarctions of the latter kidneys all but one had mineral salt deposits The morphologic changes attributable to the experiment were in 2 kidneys found in fairly large areas of the parenchyma affecting both glomeruli and tubuli, in the remaining 5 the tubuli alone were affected to a slight or moderate degree One of the 2 kidneys in which the selective catheterization failed was included in the latter The mineral salt deposits were fairly extensive in one kidney and moderate in the remainder The macroscopic appearances indicated infarction in 2 of the kidneys

In the *third group* with selective catheterization of the renal arteries as far distally as possible and injection of contrast medium the angionephrographic effect was normal in 4 and abnormal in 3 of the 8 kidneys No films were obtained in one kidney owing to a technical fault One of the 3 kidneys with an abnormal angionephrographic effect was studied only for 20 seconds during this time the accumulation of the contrast medium in the upper part of the kidney remained unchanged and in addition the interlobar arteries in the area failed to empty The accumulation of contrast medium was still evident 4 to 5 minutes respectively after the injection in the upper and lower parts of the 2 remaining kidneys (Fig 2) In one of these cases regional interlobar arteries also remained filled longer than normal Renal aortographies in two dogs including two of these kidneys revealed however a normal angionephrographic effect

The dogs were killed after intervals ranging from 4 1/2 to 5 1/2 weeks Histologic examination disclosed slight pyelonephritic changes in 7 kidneys Two kidneys had infarctions with affection of the tubuli and considerable mineral salt deposits the infarctions occurred in one of the kidneys with a normal and in one that had shown an abnormal angionephrographic effect The morphologic changes in the former were evident in one small area and in the latter were scattered and moderate in degree The infarctions were not obvious macroscopically

Discussion

The risks of selective catheterization and arteriography have been discussed in recent papers on experimental studies EDLING et coll (1959) found that the injection of large doses of contrast medium is usually followed by renal injury but there was no constant relationship between the dose of the contrast medium and its concentration on the one hand and the degree of renal damage



Fig. 2. Selective catheterization of the upper right renal artery 20 sec. after injection of 0.1 ml/kg bodyweight Urografin 30. Abnormal angio-nephrographic effect in the upper part of the kidney still evident after 5 min. Only small infarctions with mineral salt deposits were evident histologically.



Fig. 3. Bilateral selective renal catheterization as far distally as possible and aortography by means of a third catheter (only left kidney reproduced). Filling defects most probably representing thrombi at tip of catheter; branches of the artery well filled. No infarctions histologically.

on the other. It was suggested that the renal damage was caused not only by the contrast medium but also by ischaemia, which increases its nephrotoxic effect. When present, an abnormal angionephrographic effect indicates a disturbance of the renal circulation. Other authors have reported a more constant relationship between the type and concentration of the medium and renal damage. LINDGREN (1961) and MORRIS, LASSER et coll. (1961) found injury to be related to the exposure of the kidney vessels to the contrast medium. The latter authors presumed however that unidentified factors may play a role in the production of nephropathy. STOKES & BERNARD (1961) suggested that peculiarities of molecular structure might be the more likely reason for the enigmatic nephrotoxic behaviour of one medium relative to another.

There is a significant difference between the experiments of EDLING et coll. and others. The former used a technique comparable with that employed in clinical examinations in human subjects. LINDGREN exposed the renal arteries through a retroperitoneal route and directed the blood flow via an extra-corporal blood-carrying tube into which the contrast medium was injected. MORRIS, LASSER et coll. explored the kidneys after abdominal incision but

made the injections by the Seldinger method STOKES & BERNARD explored the renal arteries and performed direct injections

The present experiments were also performed with a technique used as a routine in clinical examinations in order to study the risks of the method The selective catheterizations were performed both proximally and as far distally as possible in the renal arteries Diatrizoate in different concentrations was the only organic iodine compound used, sodium iodide in a plasma isosmotic concentration was injected into one artery at the same time as in part of the series the diatrizoate was injected into the other for a comparative study of the angionephrographic effect (EDLING & OVENFORS 1962)

There was as the results indicate no consistent relationship between the variations in the technique and the histologic findings in the kidneys The selective catheterization without and with contrast medium of varying con centrations and amounts caused renal damage in some dogs or, in some cases only in one kidney The incidence of injury was highest in the group with careful catheterization In the group in which it was the intention to occlude the arteries by the catheterization and additional contrast medium injection no signs of injury were evident in the majority of kidneys As in the previous examinations of EDLING et coll some factor other than the catheterization itself or the contrast medium again seemed to contribute to the injury

Every selective catheterization naturally causes a reduction in the renal blood flow and an impairment in renal function The degree of disturbance may vary It is difficult to produce complete obstruction of the renal artery when a normal branching pattern is present even when the tips of the catheters lie distally On the other hand, occlusion may result if the catheter enters a narrow or a branch of early origin (BOIJSEN 1959)

The inconstant relationship between the present experimental technique and the renal damage indicates that this is due to a factor that can operate during any experiment It is well known that blood clotting in the catheters may quickly occur if they are not repeatedly flushed with normal saline Intra arterial filling defects most probably representing blood clots were demonstra ted in one case in the present series (Fig 3) The possibility of clot formation seems always to be present irrespective of whether the catheterization is per formed carefully or not The present histologic examinations revealed that the damaged areas of the kidneys were consistent with infarction no tubular degenerative changes being found as would be expected if the damage were due to osmolarity This is in full accordance with the concept of embolus formation In the first group with a high incidence of renal injury the catheters were not withdrawn between the different bilateral injections and they remained in the arteries for more than one hour a period that must increase the risk of blood-clotting Furthermore the renal infarctions in a dog in which catheterization failed indicate that attempted catheterization may also produce this condition An abnormal angionephrographic effect when present most

probably represents a temporary disturbance of renal circulation as this is not associated with corresponding morphologic changes in the kidneys No changes attributable to the diatrizoate compound or the sodium iodide solution were demonstrable

The presence of massive mineral salt deposits in the infarcted areas as early as 1 to 3 weeks after the injury may appear strange This, however, is in accordance with the experiences of pathologists in human subjects Boyd (1943) noted that even short temporary obstruction of the renal artery in the rabbit may be followed by extensive calcification of the kidney It may be mentioned that infarctions of the kidneys were also reported by Edling et coll (1959) although they were not then discussed in the present context

It would thus appear that the renal damage resulting from the present experiments was due to attempted or successful selective catheterization of the renal artery with infarction due to thrombus formation and emboli This complication is of a different character from that caused by osmolarity when too large doses of hypertonic contrast media are used We believe that the same complication may arise in clinical selective catheterization, although by reason of the larger caliber of the vessels and the more rapid examinations the risk of an embolus is much reduced, when it has occurred its presence may not have been evident clinically

SUMMARY

Unpredictable injury occurred with variations of technique in experimental studies of selective renal catheterization and arteriography in 18 dogs It is suggested that the affected kidneys were damaged by emboli due to clot formation during the catheterization

ZUSAMMENFASSUNG

Unvoraussiehbare Verletzungen erfolgten nach verschiedenartigen technischen Ausführungen der selektiven renalen Katheterisierung und Angiographie bei 18 Hunden im Experiment Es wird angenommen dass die Nierenschaden durch Embolie erfolgten die durch die Katheterisierung bedingt waren

RÉSUMÉ

Des variations de la technique au cours d une étude expérimentale sur 18 chiens du cathétérisme et de l artériographie rénale sélective ont entrainé des lésions imprévisibles Les auteurs pensent que ces lésions rénales sont dues à des embolies causées par la formation de caillots pendant le cathétérisme

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RENAL CIRCULATION TIME IN RABBITS STUDIED WITH CINEANGIOGRAPHY

by

ROLF KOHLER and WIGHER MORTENSSON

Renal angiography has mainly been used in the investigation of morphologic problems The method is however also useful for studying certain physiologic phenomena of theoretical and clinical interest e g the intrarenal circulation time The present experimental investigation was therefore undertaken to obtain a conception of the renal circulation time with a clinically applicable method viz renal cineangiography

Roentgen methods in the studies of the intrarenal circulation time have often been reported in the literature FABRE (1955) found that the renal venous phase in lumbar aortography lasts from about 6 to 15 sec after the beginning of the injection LINDGREN (1953) using the catheter method for aortic renal angiography with the systolic blood pressure reduced to 85 mm, reported that the veins are usually not filled with contrast medium until about 15 sec after the end of the injection EDSMAN (1957) observed a filling of the larger renal veins in the hilum and the main renal vein 4 to 15 sec after the injection of medium TRUETA et coll (1947) studied the renal circulation time in the rabbit experimentally by direct cineradiography after thorium dioxide had been injected into the jugular vein and reported that the optimum time to demonstrate the renal vein was from 3 to 4 sec after the

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renal artery was best seen HELANDER (1958) measured the renal circulation time in experimental investigations of the nephrographic effect On selective renal angiography of 7 dogs with 5 ml sodium diprotrizoate (Miokon) 30 or 50 % and an injection time of 1 to 2 sec the renal vein could be recognized after 2 to 3 sec One dog was examined bilaterally A dose of 8 ml Miokon 50 % was injected into one of the renal arteries and a similar amount of thorium dioxide suspension (Thorotrast) into the other The injection time was 6 5 sec The renal vein was demonstrable after 7 sec in the former experiment but as early as 3 5 sec when the Thorotrast was injected

The circulation times for the rabbit and the dog were thus 3 to 4 sec in the experiments with thorium dioxide The corresponding times were 2 to 3 and 7 sec in dogs studied with sodium diprotrizoate in doses of 5 ml and 8 ml respectively The values vary still more namely between 4 and 15 sec in clinical investigations This demonstrates the necessity of a systematic investigation of the normal renal circulation time as a point of departure in the evaluation of the time under pathologic conditions

Material and Methods Thirty one injections of Thorotrast and 30 of Urografin were made in 19 rabbits weighing about 3 kg to determine the renal circulation time at renal angiography with the aid of cineradiography The animals were anaesthetized with mebumal intraperitoneally and then mounted on their backs The anaesthesia was kept as superficial as possible, and supplemented with local anaesthesia of the right groin A plastic catheter (PE 160) was inserted into the right femoral artery through an incision in its wall the tip of the catheter being passed up to the level of the second lumbar vertebra The contrast medium was injected via the catheter and the catheter was connected to a manometer for registration of the blood pressure Switching over of the catheter to the manometer and registration of the blood pressure required only a few seconds

It is easier to study the left kidney because the extrarenal vessels are longer and therefore easier to recognize by carefully turning the animal to the right side the main part of the otherwise disturbing mesenteric vessels may however be projected outside the examination field

Diatrizoate sodium + methylglucamine diatrizoate (Urografin) 76 % as well as thorium dioxide suspension (Thorotrast) 25 % were employed The contrast medium was injected by hand and double injections of the same preparation were often given The injection time was about 0 33 sec for 2 ml and somewhat shorter for one milliliter of the medium The interval between two injections was at least 2 to 3 min in order to prevent the venous phase of the first injection interfering with that of the second

The dose of the contrast medium was 2 ml per injection with but a few exceptions This dose was large enough to demonstrate the veins when Thorotrast was used but the initial filling of the renal vein could not always be timed

with accuracy when Urografin was injected The circulation time did not vary with the size of the dose but it was easier to distinguish the various phases of the examination when 2 ml were administered It would perhaps have been still easier to time the phases if the dose had been increased further but this would have meant an unnecessary increase of the already heavy stress on the kidneys

The cineradiographic recording with an enlargement of 2 1 was performed with a 35 mm Arriflex camera and a Philips 9 ′ image intensifier centred above the hilum of the left kidney The angiographic course of the injection was followed in a TV monitor connected to the intensifier The injections were given after the camera had been started and films were obtained until the renal vein could be distinctly recognized, or when the vein could not be discerned — generally after 5 to 6 sec The speed of the film was checked at the beginning and the end of a roll and was found to be 46 frames/sec The focus was 0 3 × 0 3 mm and the exposure values about 3 mA and 60 to 70 kV

The films were studied with the aid of a projector provided with a film counter The intrarenal circulation time was calculated from the number of exposures, counted from the moment the contrast medium injected into the renal artery entered the kidney until the renal vein could be recognized in the renal hilum When the anaesthesia was too superficial the rabbit reacted to the injections of Urografin 76 % and moved, making it difficult or impossible to see when the contrast medium began to fill the renal vein If this could not be fixed with an accuracy of 5 exposures, i e 0 1 sec, the examination was not included For this reason 13 of the 30 injections of Urografin 76 % were excluded

Results

1 The central value for the intrarenal circulation time determined by the method described above was 1 52 sec (range 1 13 to 1 91 sec) when Thorotrast was used and 1 78 sec (1 47 to 2 0 sec) when Urografin 76 % was employed

2 The circulation times determined with the same amount and kind of contrast medium in one and the same animal differed but little from one examination to another — on the average 0 13 sec

3 The circulation time was not influenced by small differences in the amount of medium injected at a standardized rate or by a variation of 10 to 15 mm Hg in the blood pressure

4 Thorotrast 12 % produced no change in the circulation time but when Urografin 50 % was used the circulation times were longer and reached about 3 sec

Discussion

The intrarenal circulation time noted in the present investigation approached the lower limit of the ranges reported in the literature

The values given by previous workers in this field, even those by TRUETA et coll (2 7 to 4 0 sec) in rabbits are however, not strictly comparable with those in the present investigation as the amount injected was 2 ml Thorotrast direct cineradiography with a recording rate of 3 3 frames/sec was used and the contrast medium was injected into the jugular vein They gave no definite figures as to the rate of injection but simply stated that the contrast medium was injected rapidly

HELANDER s values for dogs 2 to 7 sec, were obtained by a very different method designed for purposes other than the determination of the intrarenal circulation time In the light of the present findings it appears remarkable that bilateral selective renal angiography in a dog with equal doses of Miokon and Thorotrast gave values of 7 and 3 5 sec respectively as measured with a recording rate of 2 frames/sec while the present values for a water soluble iodine contrast medium and corpuscular thorium dioxide respectively, differed from one another on the average by only 0 25 sec

It would appear to the writers that the higher values found for the renal circulation time by HELANDER may be due to the fact that he used a much lower injection rate with consequent increased admixture of blood which makes it difficult to time the initial filling of the vein with medium As to the iodine contrast medium, the lower the rate of injection, the greater the amount excreted by the tubules A given decrease in the rate of injection thus produces a greater increase in the observed circulation time of the water soluble medium than that recorded with Thorotrast This may help to explain why HELANDER found such a difference between the circulation times noted in his experiments with Thorotrast and Miokon, accentuated by the fact that he used Miokon 50 % as against Urografin 76 % employed in the present studies The effect of the concentration of the water soluble contrast medium on the recordings of the renal circulation time has been stressed above

According to HELANDER the explanation of the time lag between Miokon and Thorium injections may be that in the initial Miokon phase the renal parenchyma takes up such a large amount of medium that the quantity remaining in the blood is not sufficient to render the renal vein demonstrable the vein becomes visible when the tubular epithelium is saturated with the medium Thorium dioxide on the other hand never passes outside the blood vessels The circulation time with Urografin 76 % in the present experiments was 0 25 sec longer than that of Thorotrast This difference might be ascribed to the above mentioned property of the tubular epithelium in association with the glomerular filtration Water soluble contrast medium must however also pass in the opposite direction i e from the renal tissue to the blood stream because after an injection of Urografin the renal vein was not void of medium until 6 to 8 sec

later, as against 3 to 4 sec for the same amount of Thorotrast injected at the same speed

A third factor that can have an effect on the difference in the circulation time between Urografin and Thorotrast is the osmotic pressure of the contrast medium Water is nearly instantaneously drawn from the tissue when a contrast medium with a strong osmotic action is injected into an artery (HOL) The osmotic action is much higher for water soluble iodinated contrast media than for Thorotrast The iodinated media will thus be considerably more diluted by tissue fluid than Thorotrast

Another factor that may influence the renal circulation time recorded is the effect of the contrast medium on the blood pressure AMUNDSEN et coll (1956) found that when Nycotrast was used for angiocardiography and aortography the blood pressure sometimes fell by as much as 40 mm 10 to 29 sec after the injection MUTH (1962) observed at most a slight fall in the blood pressure on injection of 10 ml Urografin 60 % into dogs In the present investigation an injection of Urografin was often followed by a fall in blood pressure of 5 to 10 mm with an equally large increase above the original value This variation in the blood pressure, however, had no effect on the renal circulation time The injection of Thorotrast was not followed by any change in the blood pressure, an observation that agrees with the one made by TRUETA et coll

The rate of flow of the medium through the blood vessels is presumably also dependent on its viscosity GREITZ in his cerebral angiographic studies found Triurol 25 % to give a shorter circulation time than Triurol 50 % No change in the circulation time with various dilutions of Thorotrast was observed in the present experiments but no other studies of the possible effect of the viscosity on the circulation time were undertaken

Any vasoconstrictive or vasodilative effect of a contrast medium may also influence the circulation time Thorotrast is said to have no effect on the width of vessels when given in doses of less than 5 ml/kg bodyweight (IRWIN) SCHMIDT (1955) reported no dilatation of the pial vessels on injection of Thorotrast or Urografin 40 % into the carotid artery, but he found an injection of Urografin 76 % to cause vasodilation LINDGREN & TORNELL (1958) observed *slight dilatation of the arteries of the intestine and limbs after the* intraarterial injection of sodium diatrizoate LINDGREN (1961) noted no change in the renal blood flow after repeated injections of 0 8 ml of sodium diatrizoate 50 % selectively into the renal artery of experimental animals, and MUTH could record no increase in the pressure in the intrarenal veins to suggest dilatation of renal arterioles during renal angiography in dogs The width of the renal artery and of the visible intrarenal arterial branches remained unchanged, irrespective of the medium used, in the present experiments

Anaesthesia may influence renal function CRAIG, VISSCHER & HOUCK (1945) reported that during deep anaesthesia the renal blood flow sometimes decreased, in superficial anaesthesia, on the other hand, little or no changes

were evident TRUETA et coll noted that in prolonged anaesthesia the circulation times tended to be slightly longer The present experiments which lasted for 1 to 1 5 hours were carried out under as superficial anaesthesia as possible It is therefore felt that the anaesthesia had no appreciable effect on the circulation time

SUMMARY

The intrarenal circulation time was determined in rabbits by direct cineradiography with injection of contrast medium into the aorta and was found to be about 1 5 seconds The time as measured with Urografin 76 % was 0 25 second longer than that noted for Thorotrast Factors capable of influencing the time recorded are discussed

ZUSAMMENFASSUNG

Nach Injektion von Kontrastsubstanzen in die Aorta von Kaninchen wurde die Verweilszeit in der Niere mittels direkter Cineradiographie gemessen und als 1 5 sec ermittelt Die Verweilszeit fur Urografin 76 war etwa 0 25 sec langer als fur Thorotrast Die Umstande die die Verweilszeit beeinflussen konnen werden diskutiert

RÉSUMÉ

Le temps de circulation intrarénal a été mesuré sur des lapins par cinéradiographie directe par injection du moyen de contraste dans l aorte il est d environ 1 5 seconde Ce temps mesuré avec l Urografin à 76 est de 0 25 seconde plus long que celui constaté pour le Thorotrast Les auteurs examinent les facteurs qui peuvent influer sur le temps enregistré

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CALCIFIED APPENDICES EPIPLOICAE

by

G. B. ELLIOTT and K. A. ELLIOTT

Infarction of the bulbous oval appendices epiploicae with saponification and calcification occurs commonly and is often asymptomatic (MURDIE 1953, ELLIOTT & FREIGANG 1962). Identical aseptic necrosis in the terminal fringes of greater omentum, a closely related structure, also produces confusing calcifications with the same characteristics and which may also lie in the true pelvis.

Their radiologic characteristics do not appear to have been reviewed. They form the clinical counterpart of experimental knowledge, largely radiologic in derivation, concerning the nature of migration of the greater omentum (ROTHENBERG & ROSENBLATT 1942, ALLEN 1954).

Case reports

Case 1. A 69 year-old hypertensive woman with generalized osteoarthritis complaining of recurrent haematuria with urinary *frequency*. *She was found to have* cystitis and during investigation an oval calcified body (Fig. 1) was detected; no symptoms in her history were referable to an intestinal complaint.

Case 2. A 72 year-old man with a three year history of diminution of urinary stream and frequency was found to have smooth *prostatic* enlargement. During pyelography a calcified ovoid was seen to fall with a tumbling movement into the left pelvis (Fig. 2). No abdominal discomfort was experienced at the time and no dyspeptic complaints were recalled.

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Fig. 1. Case 1. Oval calcification with a characteristic dense shell which in successive films shifted slightly at the level of the pelvi-rectal pouch.

Case 3. A 70-year-old silicotic ex-miner complained of pain of pleuritic type in lower left chest and epigastrium. During a gastro-intestinal series a cluster of four ovoid calcification deposits were noted incidentally medial to the descending colon. On re-examination 2 1/2 years later they had moved to the opposite abdominal quadrant en bloc (Fig. 3).

Case 4. A 44-year-old nurse with a three-year history of hypermenorrhoea and anaemia but without any history of dyspepsia or abdominal pain. During vaginal hysterectomy a smooth, hard, tan-colored peritoneal loose body was found lying free in the pelvi-rectal pouch (Fig. 4). The point of origin was not determined. On section it showed a fine calcific shell enclosing grumous fatty debris. Microscopically it showed the features of an old infarcted and calcified appendix epiploica.

Discussion

Ross (1950) has described 'the appendices epiploicae are situated like flags marking the course of the vasa recta longa on the colon wall'. Sufficient slack is present in these encircling vessels to accommodate normal distensions of the intestine. One function of appendices epiploicae is to act as recesses into which these vessels prolapse when the colon is empty (PINES et coll. 1941). They are among the last fat depots to be used during weight loss and are in constant slow fluttering motion during colonic movement (HARRIGAN 1917). Localized terminal infarctions due to aseptic necrosis are very common in them. This appears due to simple alterations in colonic posture producing crease-like folds in these bulbous adipose structures. Although a recognizable clinical syndrome has been described in the acute cases, consisting of continuous mild abdominal pain, all within an area corresponding with the contour of colon, lasting without exacerbation for days, and without pain shift, rigidity or loss of appetite, the majority of instances appear to be asymptomatic (ELLIOTT & FREIGANG 1962).

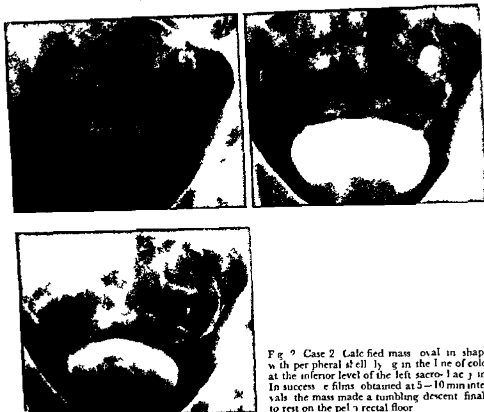


Fig 2 Case 2 Calcified mass oval in shape with peripheral shell lying in the line of colon at the inferior level of the left sacro-iliac joint In successive films obtained at 5—10 min intervals the mass made a tumbling descent finally to rest on the pelvi rectal floor

The terminal infarcted bulb of such appendices epiploicae may calcify and finally detach silently from its moorings to produce a loose body which gravitates into the pouch of Douglas Discovered at laparotomy they sometimes very closely resemble fecoliths They are occasionally covered with a thin fibrinous exudate but are usually smooth and hard

Radiologically the terminal calcification is characteristically ovoid or almond shaped with a crisp shell like rim enclosing a homogeneous less dense core (Barden 1939) The size usually ranges from 0 5 to 1 5 cm in maximum diameter and deposits may occasionally be multiple in a small row in line with the colon When loose they are freely mobile and change in position in the recto vesical pouch during different body postures (Barden 1939 Morales 1944) In supine position they have been seen to move proximally in the pelvis and lie typically just below the sacro-iliac joint on either side During urography and gastro-intestinal examinations they can be shown to lie outside all adjacent organs An apparently identical process occurs in the free margin of the greater omentum also with aseptic infarction subsequent saponification

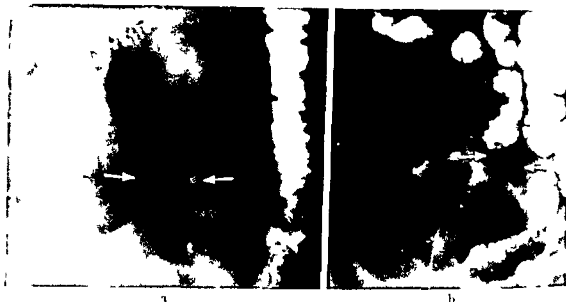


Fig. 3. Case 3. (a) A cluster of 4 calcified ovoids lying outside the descending colon, contrasting with two denser calcified mesenteric lymph nodes. (b) Film obtained 2 1/2 years after (a). The cluster of multangular calcified ovoid has moved into the right iliac fossa while preserving their interrelationship.

and identical ovoid shell like calcification (HULTEN 1927) but seldom with separation. As the inferior margin of the greater omentum commonly hangs as low as the floor of the true pelvis, such calcifications lead to a considerable degree of confusion with the other causes of calcification in this zone. When closely contiguous they may be of a somewhat facetted appearance and imitate semi opaque biliary calculi if located in the right upper quadrant (HOLT & MACINTYRE 1948). These lesions are often present in a small cluster, which moves from quadrant to quadrant with the marked degree of mobility of the greater omentum, but characteristically preserve their interrelations.

It is noteworthy that epiploic calcifications do not increase progressively in density but persist unchanged in appearance over long periods. One confirmed instance seen by HOLT & MACINTYRE was followed for eight years.

The differential diagnosis. Multiple incompletely annular calcifications scattered at random, and fixed in the peritoneum, with steady increase in density, have been described in unusual solitary cases of peritoneal pseudo myxoma (PUGH 1942) (WEIG et coll. 1944). This condition is not typified by such changes. Marginal calcification forming incomplete rings is also recorded around pelvic paraffinomas (CRUICKSHANK 1931, PUGH 1942), which follow injection of mineral oil into the peritoneum in the misguided hope of preventing adhesions.

The earlier descriptions of sterile intraperitoneal loose bodies referred to a central core of crystalline calcium phosphate (HARRIGAN 1917) in a fibrinoid capsule (ROSS & MCQUEEN 1948). As detached appendices epiploicae are the

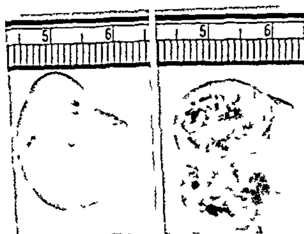


Fig 4 Case 4 A typical peritoneal loose mass with central pultaceous core inside a fibrocalcareous shell

commonest source of such loose bodies this non specific appearance came to be accepted by repetition in text books It has been associated with loose intraperitoneal bodies of a much larger size than appendices epiploicae, for example one of hen s egg size which impacted, causing retention of urine (SHEPHERD 1951) It is likely that such masses were of quite other origins

A very common form of calcification is usually accepted to be calcified phlebolibths in pelvic veins or occasionally in the spleen They are typically more homogeneous multiple round small and clear cut Urinary tract calculi are usually very dense and in the bladder may be mobile well defined and rounded Calcification in mesenteric lymph nodes commonly post tuberculous is much more coarse and granular in character and often with a lobulated edge They are not easily confused despite some mobility from their mesenteric position As with all these other causes of rounded pelvic calcifications they do not appear as a dense peripheral shell surrounding a more homogeneous and less dense centre

ALLEN in an experimental radiologic study showed that the position of the greater omentum in dogs was almost entirely determined by gravity producing a series of passive curtain raising and lowering effects In children the omentum is small and thus ineffectual in sealing off peritonitis

Greater omental calcifications tend to remain attached, forming the clinical counterpart of experimental indicators in dogs Using calcified clusters of fatty appendages in the lower margin of the greater omentum as markers it is evident from Case 2 of HOLT & MACINTYRE (1948), and our Case 3 that marked migrational shifts of omental edge also occur frequently in man It moves to widely varying quadrants of the abdomen inferior to its base of attachment and changes may be rapid HOLT & MACINTYRE s case showed

shifts to three different abdominal quadrants during one day The continual protection afforded by passive gravitational sweeping of this vascular homograft is immense We feel that this is the true phylogenetic function of greater omentum, one of the largest, yet least studied, body structures

SUMMARY

Report of three cases of mobile oval calcifications in appendices epiploicae and the greater omental fringe showing a characteristic shell like rim enclosing a homogeneous but less dense core

ZUSAMMENFASSUNG

Drei Fälle von ringformiger Verkalkung in den Appendices epiploicae und im unteren Rande des Omentum werden beschrieben mit ihrer typischen schalenartigen Umrandung und mit ihren homogenen mehr strahlendurchlassigen und beweglichen Zentren

RÉSUMÉ

Présentation de trois cas de calcifications annulaires dans des appendices épiploïques et dans la frange du grand épiploon formées d une coque caractéristique entourant un noyau homogene et mobile mais moins dense

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THE SUBTRACTION METHOD

by

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Ziedses des Plantes (1934) published the first description of the subtraction technique applied to roentgen diagnostic work and stated that a difference between two roentgenograms of the same part of the body may be made apparent by covering one of them with a diapositive of the other. For example, when the subtraction technique is applied to angiography all bony structures are removed and only the vessels remain. A further advantage of the subtraction method is that the differences in density of the original films are equalized and the interpretation made easier. This and other applications of the method have been described in several additional papers by Ziedses des Plantes between 1934 and 1961. The method appears however to have remained widely unknown or neglected because of presumed difficulties, especially in making satisfactory positive copies or masks by a routine method.

Growing interest in the method has recently been reflected in papers by Hanafee & Stout, Levick & Mitchell, and Vezina & McRae, all published in 1962. These clearly indicate the diagnostic value of the procedure, which however still appears to be liable to errors and sometimes is complicated in spite of attempts to simplify it.

Two different techniques to produce a positive copy have been described. One utilizes the light produced by one of the intensifying screens in a roentgen

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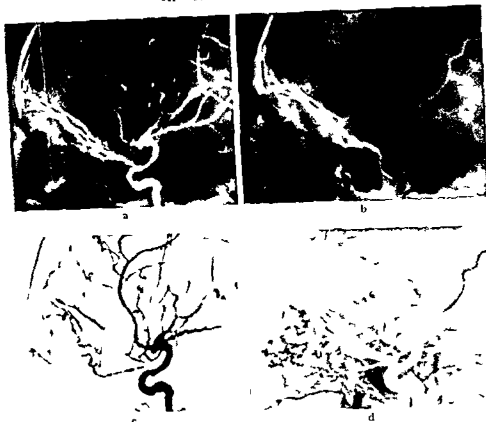


Fig 1 Malignant neurinoma of the orbit (a) Arterial phase b) Early venous phase c) Subtraction of (a) Displacement of arteries d) Subtraction of (a) and (b) Early arterial phase (white) combined with pathologic vessels in the tumour filled at later stage (black)

casette (LEVICK & MITCHELL and VEZINA & McRAE) The other is purely photographic the direct positive copy being made by means of ordinary light ZIEDSES DES PLANTES originally employed the former method but later abandoned it in favour of the latter Attempts have been made to develop a technique for obtaining positive copies in a simple and practical manner by either method but although different films developers and exposures have been tried a standard technique has not yet been evolved Among the disadvantages quoted are the need for specially trained personnel and the excessive time consumption

The subtraction method has been employed for several years at Serafimer lasarettet It would appear to the writers that the photographic method of producing the positive copy is the simplest and easiest During the past two years it has become the routine procedure We consider it possible to apply the method in all cases independently of individual variations and therefore



Fig. 2. Angioreticuloma. a) Late venous phase. b) Tumour and drainage veins clearly visible after subtraction.

present the step by step details of a procedure that has been found to provide constant and uniform results. The method has proved to be of great value, and, in fact, frequently *indispensable, in angiography*, although its application may well be extended to other aspects of the diagnostic work.

Material. In order to produce a positive copy of a roentgenogram it is necessary to use a single coated film possessing a long straight density curve of 45° gradient, i.e. $\gamma = 1$, and a short toe. The developer should also be capable of giving a contrast $\gamma = 1$ without difficulty. These conditions must prevail if the photographic contrast is to be as near to the original as possible.

Most manufacturers of photographic film produce graphic films and developers of such characteristics. We have tried 'Agfa Phototechnischer Film', type B, with Agfa Varitol normal, Gevaert Graphic Non Ortho, N 33 with Metinal U, Kodak Commercial film, or 33 positive film with DK 50 all with their particular developers. Some of the developers are liquid concentrates and some are stock solutions to be diluted; these may be stored for a considerable period. All these film developer combinations have been tried, and no essential differences have been found between them. All the films now mentioned are blue sensitive, an essential feature to enable processing to be carried out in the ordinary darkroom of a roentgen department. The developing time is the most critical part of the whole procedure.

Technique

1. *Preparation.* The developer, in the case of Agfa Varitol, is diluted with double its volume of water, or, if it is Metinal U, with the same volume. An additional tray containing 2 % acetic acid is prepared.



Fig 3 Caro id ca ernous fistula a) Orig nal b) Subtraction Contrast fill ng of the intercavernous s u the cavernous s nus on the opposite side and several dra nage veins



F g 4 Contrast fill ng of the ophthalm c vein n a case of ca ot d ca ernous fistula Bony structu es p act cally el m nated by subt action filling of the choroid plexus n the eye with the ret na

2 *Exposure of the diapositive* It is practically impossible in the safelight to detect the coated side an identifying notch is therefore cut out during manu facture in one of the short ends of the film The film is placed with the emulsion side up on a flat background the selected roentgen film being placed on top of it and both covered with a sheet of glass The film is exposed by switching

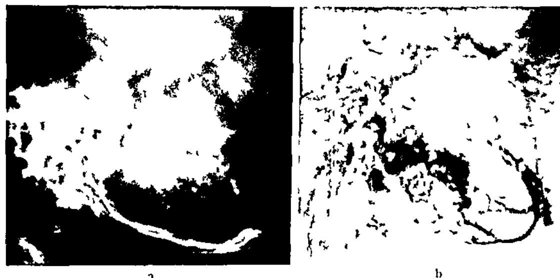


Fig. 2. Angioreticuloma. a) Late venous phase. b) Tumour and drainage veins clearly visible after subtraction.

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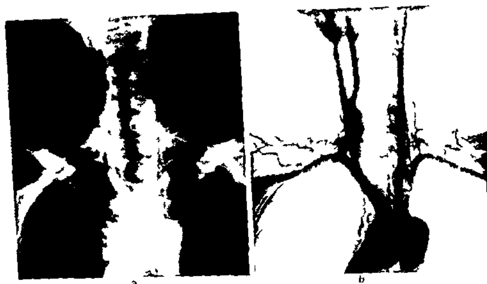


Fig. 6 Filling of arteries of the neck after contrast injection into the right atrium a) Original b) Subtraction

fully inspected so that corresponding structures are exactly superimposed. This critical part of the operation should be performed on a shielded brightly illuminated box in an otherwise darkened room. If difficulties are encountered, the work should be concentrated on matching the area under investigation. The superimposition is facilitated if metal indicators are set on the grid before exposure of the roentgenograms. The mask and the film are taped together when they have been perfectly matched.

6 *Subtraction*. A copy of the combined mask and film, depending on the purpose, is made either on paper or film. If paper is used it should be hard bromide, if film it should be a single coated graphic film. The simplest way is to use the same type of film as has been used for obtaining the mask. The same exposure procedure as under (2) is used but longer exposure times are usually required. Finally, after exposure, the subtraction film is developed, fixed and dried as an ordinary roentgen film, preferably in an automatic processing unit.

Discussion

The *prerequisites* for using the subtraction method are that two roentgenograms have been obtained with the relevant part of the subject in the same position but with certain differences between the two roentgenograms, as for instance the presence of contrast medium in one of them. Both the



Fig 5 Osteochondroma a) Trabeculae differentiation between bony structures and vessels not possible in original b) Subtraction No vessels evident inside tumour

on the light source, situated perpendicularly above the film centre (See also later)

3 *Development* The processing of the film is a critical procedure and must be timed with a chronometer The developer must be freshly diluted and have a temperature of 20 ± 0 5° C The film is gently agitated in the developer for the necessary time (Agfa film + Varitol 45 sec) Development of the film is arrested by its transfer to the 2 % acetic acid bath

4 *Fixation and drying* The same fixing bath as for an ordinary roentgen film is used rinsing and drying are also identical Should an automatic processing unit be available in which access may be gained to the fixing bath, this will naturally be employed for the fixing, washing and drying The positive copy, or the mask, is then ready

5 *Superimposition* The mask is superimposed on the roentgen film from which the details are to be subtracted The mask and the film must be care

It is possible in selecting films for subtraction masking to adopt a method used in military circles A certain sector under surveillance is photographed every day under identical circumstances The photographs are placed in a stereoviewer, and any changes that may have taken place can be detected by the almost three dimensional effect of the addition The stereoviewer may be used in a similar manner for selecting films for subtraction We have tested this method and found it useful

Either an ordinary photographic enlarger, or a frosted incandescent bulb at a distance of one to two meters may be used as a source of light in the exposure of the diapositive The exposure time must be determined in relation to the intensity of the light source because of the straight density curve of the film it is not critical An exposure time in the range of half or double that of the optimum will yield acceptable results If the direct positive copy is somewhat darker or lighter than the original roentgen film this will only alter the density of the combined films while the masking effect will remain practically unchanged Tests must be carried out to establish the optimal exposure times both for producing the mask and the final film or paper copy before subtraction can become a routine procedure

The development of the film is critical if correct contrast is to be obtained The recommendation made by LEVICK & MITCHELL of visual inspection of the film during its development cannot therefore be accepted Such inspection is in any case not easy and would hinder the establishment of a standard routine The correct developing time should be established through tests with films or film strips before settling on a routine Three or four strips of the diapositive film are usually sufficient These are exposed together with the original film for the same period but developed for different lengths of time e g 1 min 1 min 15 sec and so on up to 2 minutes for Agfa film The developing process is then stopped and the strips are fixed, rinsed and dried and superimposed on the original film the one producing the best obliteration of the structures representing the ideal developing time with $\gamma = 1$ All other sensitometric methods are superfluous

Once the procedure has been established it is quite feasible to adopt subtraction as a part of the routine work in the roentgen department Apart from the selection of cases to be examined the choice of films to be compared and preferably also the superimposition of the diapositive mask on the roentgenogram all of which must be handled by the radiologist, the operation can be handled by the ordinary darkroom personnel Actual working time per case would appear to amount to about four or five minutes plus the time required in the automatic processing unit

HANAFEE & STOUT (1962) stated that photography like medicine, is more of an art than a science and that too many variables exist to allow a rigid one two-three-step technique This statement has fortunately not been borne out by the facts



Fig. 7. Nephroangiography of hypernephroma immobilizing the right kidney. Subtraction from two films at different stages of breathing. The left kidney moves normally. The method may thus also be used for studying the mobility of organs.

roentgenograms must have been developed and in all respects processed in an identical way. It is self evident that the use of an automatic rapid film changer simplifies the gathering of primary material. An automatic processing unit also guarantees that the roentgenograms are similarly processed. Any need for special fixation of the part examined, as suggested e. g. by ZIEDSES DES PLANTES, has not been found necessary in cerebral and peripheral angiography.

Selection of two suitable roentgenograms in which subtraction may yield valuable results is naturally of great importance. It is generally advantageous if one of the pair is without contrast filling of the vessels, although it is possible to combine films from different phases, as long as it is borne in mind that all corresponding details will be eliminated: valuable information is sometimes thus obtained (Fig. 2). The chief thing is that the examiner knows what he is aiming at detecting by the elimination of bony structures that obscure other details.

We consider the subtraction method of particular value in angiography because the vessels are sometimes obscured by bony structures. The results obtained with the method are comparable with those obtainable with the complicated method known as angiotomography. Care must be taken, in the examination of organs that move during the respiratory cycle, to ensure that the two films are from the same respiratory phase, and in the examination of the heart they must furthermore be from the same cardiac cycle.

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ORTHODIAGRAPHIC PELVIMETRY WITH SPECIAL REFERENCE TO CAPACITY OF DISTAL PART OF PELVIS AND PELVIC OUTLET

by

U. BORELL and C. RADBERG

The current variations in methods of pelvimetry would appear in some measure to reflect the difference in opinion as to which pelvic diameter or combination of diameters affords information of diagnostic and prognostic value, particularly if the capacity of the distal part of the pelvis is to be assessed. BORELL & FERNSTRÖM (1957, 1960) correlated the width of different pelvic diameters with the course of labour. They established a relationship between the capacity of the distal part of the pelvis and the combination of one sagittal and two transverse diameters, viz. the sagittal diameter of the pelvic outlet (the distance between the lower border of the symphysis and the sacral tip), the interspinous diameter, and the posterior intertuberous diameter. These authors described a technique permitting roentgenologic measurement of these dimensions with a high degree of accuracy. The sagittal diameter of the pelvic outlet and the intertuberous diameter are determined. If the sum of these two diameters exceeds 25 cm, a disproportion can be excluded. If the sum is 25 cm or less, both the interspinous diameter and the width of the sagittal diameter

From the Department of Obstetrics and Gynaecology (Director: Prof. U. Borell) and Roentgen Department II (Director: Docent I. Wickbom), Sahlgrenska Sjukhuset, Gothenburg, Sweden. Submitted for publication 13 August 1962.

SUMMARY

The subtraction method has been developed into a routine roentgendiagnostic procedure and found to be extremely valuable and occasionally indispensable in angiography. A standard method is described.

ZUSAMMENFASSUNG

Die Subtraktionsmethode ist heute eine etablierte röntgendiagnostische Standarduntersuchungsmethode; sie ist wertvoll und bisweilen unerlässlich für die Angiographie. Die Routineanwendung der Methode wird erläutert.

RÉSUMÉ

Les auteurs ont adapté la méthode de soustraction à une utilisation courante et l'ont trouvée très utile et parfois indispensable pour l'angiographie. Ils décrivent une méthode standard.

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The current variations in methods of pelvimetry would appear in some measure to reflect the difference in opinion as to which pelvic diameter or combination of diameters affords information of diagnostic and prognostic value particularly if the capacity of the distal part of the pelvis is to be assessed Borell & Fernstrom (1957 1960) correlated the width of different pelvic diameters with the course of labour They established a relationship between the capacity of the distal part of the pelvis and the combination of one sagittal and two transverse diameters viz the sagittal diameter of the pelvic outlet the distance between the lower border of the symphysis and the sacral tip) the interspinous diameter and the posterior intertuberous diameter These authors described a technique permitting roentgenologic measurement of these dimensions with a high degree of accuracy The sagittal diameter of the pelvic outlet and the intertuberous diameter are determined If the sum of these two diameters exceeds 25 cm a disproportion can be excluded If the sum is 25 cm or less both the interspinous diameter and the width of the sagittal diameter

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of the pelvic outlet, at maximum movement at the sacro iliac joints, are measured To accomplish this, an additional a p view, and a lateral roentgenogram with the patient supine and hanging by the knees, are necessary

BORELL & FERNSTROM also measured the posterior intertuberous diameter from a view of the pubic arch *obtained by a modification of the method of* Chassard Lapine (Fig 1) The essential features of this technique were as follows The patient sat on the edge of the roentgen table, leaning well forward, with legs abducted A cassette fitted with a grid was placed between the patient s buttocks and the table The overcouch tube, with beam vertical, was used, the focus film distance being 100 cm The limits of the intertuberous diameter were considered to be the tangent points on a line drawn at a tangent to the two ischial tuberosities *As the magnification factor was regarded insignificant,* correction of the values was not required

Chassard Lapine s method is, however, unsatisfactory for several reasons One is that the patient, particularly in late pregnancy, may have difficulty in leaning sufficiently forward to allow the pubic arch to be correctly projected A correct projection means that the plane of the pubic arch is parallel to the film and perpendicular to the central beam, positioning may be difficult to judge because *suitable anatomical landmarks are lacking* Correct projection of the pubic arch is important because even a slight change in position may affect the posterior intertuberous diameter, the more the patient leans forward the more its width is reduced Furthermore, the contact points on the line drawn tangential to the ischial tuberosities, which represent the limits of the posterior intertuberous diameter, are not in direct relation to the birth canal but at some distance lateral to it

The following arguments may therefore be raised against Chassard Lapine s method it is often difficult to perform, the positioning of the projection is inexact, the magnification of the posterior intertuberous diameter, although admittedly small, is disregarded, the end points of this diameter are not in direct relation to the birth canal We have therefore abandoned *Chassard* Lapine s projection and have been using the method now to be described

Method

The diameters necessary for the estimation of the capacity of the pelvis can all be measured in two films, one a p and one lateral

Antero posterior view for measurement of the intertuberous and interspinous diameters
The ischial spines in this roentgenogram are projected within the middle or upper portion of the obturator foramina, and care is taken that the ischial tuberosities are also demonstrated The patient lies supine with the knees flexed and with the thighs abducted about 90 to prevent the medial soft tissue from concealing the two spines (Fig 2) The cassette is placed directly under the



Fig 1 Positioning of patient (Chassard-Lapiné method) for determining the intertuberous diameter (from PORELL & FERNSTRÖM 1960)



Fig 2 Positioning of patient for a p view of pelvis to determine the intertuberous and interspinous diameters by the orthodiagraphic method, no secondary grid

patient's buttocks the object film distance being thereby shortened The overcouch tube is used The focus film distance should be long we use 125 cm The light beam diaphragm is adjusted so that an area 5 to 6 cm × 10 to 11 cm is projected onto the film The central ray is directed about 20° cranially and centred over a point in the midline about 3 to 4 cm below the upper border of the symphysis Without changing the position of the patient or the film two exposures are made with the tube moved 5 cm to each side of the midline A ruler with a centimeter scale may be attached to the tube arm to facilitate the adjustment of the tube The following factors are used 40 to 45 kV and 125 mAs As a low voltage and a small field are employed the ischial spines and the ischial tuberosities are clearly demonstrated without secondary grid

The interspinous and intertuberous diameters are obtained from this view (Fig 3) The interspinous diameter is measured between the apices of the spines the intertuberous diameter being determined by a line drawn tangentially to the two ischial tuberosities the points of tangency of the line forming the limits of the dimension

The reason why the tube is moved 5 cm to the right and left respectively of the midline is that the interspinous diameter usually measures about 10 cm If the two exposures are made with the central beam in the same sagittal plane as the apices of the ischial spines the interspinous diameter as measured directly from the film constitutes the true one Calculations and experiments

of the pelvic outlet, at maximum movement at the sacro-iliac joints, are measured. To accomplish this, an additional a.p. view, and a lateral roentgenogram *with the patient supine and hanging by the knees*, are necessary.

BORELL & FERNSTRÖM also measured the posterior intertuberous diameter from a view of the pubic arch obtained by a modification of the method of Chassard-Lapiné (Fig. 1). The essential features of this technique were as follows. The patient sat on the edge of the roentgen table, leaning well forward, with legs abducted. A cassette fitted with a grid was placed between the patient's buttocks and the table. The overcouch tube, with beam vertical, was used, the focus-film distance being 100 cm. The limits of the intertuberous diameter were considered to be the tangent points on a line drawn at a tangent to the two ischial tuberosities. As the magnification factor was regarded insignificant, correction of the values was not required.

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The diameters necessary for the estimation of the capacity of the pelvis can all be measured in two films, one a.p. and one lateral.

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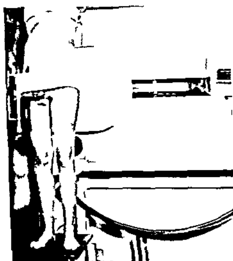


Fig 4 Positioning of patient for lateral view of pelvis th plastic od with centimeter scale is plac d on the midl ne

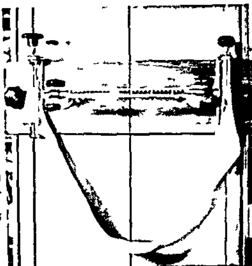


Fig 5 Plastic od with cent meter scale and com press on band attached to the S emens Universal Planigraph roentgen table

200 to 250 mAs High speed intensifying creens and rapid films are used This technique permits the end points of the sagittal diameters and the presenting part of the foetus to be clearly demonstrated (Fig 6)

Evaluation of the diameter values

According to BORELL & FERNSTROM (1960) disproportion in the distal part of the pelvis is most unlikely if the sum of the measurements of the sagittal diameter of the pelvic outlet and the interspinous and posterior intertuberous diameters as calculated from Chassard Lapine s view exceeds 34 cm If the total is less than 32 cm the prognosis for labour is unfavourable and if the total is between 32 cm and 34 cm the prediction is rather uncertain and labour may be normal or protracted It was found convenient to define these latter as border line cases

It may be assumed that the values obtained for the sagittal diameters and the interspinous diameter are approximately the same both with Borell & Fernstrom s method and the present method Some slight differences may occur because of differences in the means of determining the diameters and the magnification factor However the figures for the intertuberous diameter, as obtained with the present method are invariably lower (by about 20 %) The main reason for this is that the end points of the intertuberous diameter, are located more medially on the tuberosities in the orthodiagraphic projection than in the Chassard Lapiné s projection Furthermore the orthodiagraphic projection eliminates magnification

The sum formula of Borell & Fernstrom for assessing the capacity of the



Fig 3 A p view of pelvis (obtained with patient in position shown in fig 2) from which the intertuberous and interspinous diameters are measured ● sin of the interspinous diameter ○ sin of the intertuberous diameter

in phantoms have shown that if the beam is inaccurately centred by 1 to 2 cm, the limits of the interspinous diameter are inaccurately projected by at the most 1 mm The error is small because the object film distance is very short (5 to 7 cm) in relation to the focus film distance (125 cm) This applies also to the determination of the intertuberous diameter In the a p view in question, the end points of the intertuberous diameter are located 0 5 to 1 cm lateral to the apices of the ischial spines Experiments in phantoms have shown that by directing the central ray from 20° to 30° cranially, the intertuberous diameter is increased by only 1 to 2 mm In no instance has it been necessary to increase the angle more than 30° to project the ischial spines within the upper part of the obturator foramen

Lateral view for measurement of the sagittal diameter of the pelvic outlet (and inlet) A lateral roentgenogram, obtained with the patient erect, is shown in Fig 4 It has been shown by BORELL & FERNSTROM (1957, 1960) that the increase in width of the sagittal diameter of the pelvic outlet associated with this position, approximated that occurring with patient supine and hanging by the knees The variations in sagittal diameter with change in position of the patient result from an increase in mobility of the sacro iliac joints during pregnancy The lateral roentgenogram in Borell & Fernstrom s method is obtained with the patient lying on her side, and the sagittal diameters are determined with the aid of a centimeter scale placed in the natal cleft The centimeter scale is attached to the roentgen table to ensure that the rod is invariably parallel with the plane of the film (Fig 5)

The present writers have employed a Siemens Universal Planigraph permitting the use of a focus film distance of 140 cm With this relatively great focus film distance, the radiation dose to the maternal ovaries and foetal gonads is reduced The beam of radiation moreover becomes more parallel, which results in reduced distortion The exposure data are 120 to 130 kV, and

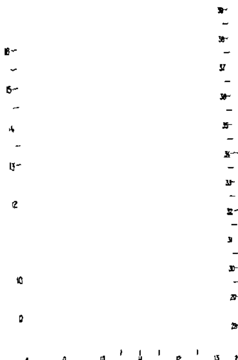


Fig 7 Measurement of the intertuberous diameter according to method of BORELL & FERNSTRÖM (ordinate) and according to the orthodiagraphic method (abscissa) ● Summation of the sagittal interspinous and intertuberous diameters exceeds 34 cm ○ Summation of the same diameters varies between 32 to 34 cm × = Summation of the same diameters is less than 32 cm

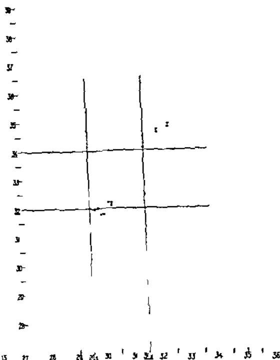


Fig 8 Summation of the three diameters in distal part of pelvis the intertuberous diameter being determined by the BORELL & FERNSTRÖM method (ordinate) and by the orthodiagraphic method (abscissa) Total of ● exceed 34 cm total of ○ varies between 32 and 34 cm total of × is less than 32 cm

The two variables are thus closely related (cf Fig 7) and the function above may be used to obtain a proper interval for S If as above the functional relationship is

$$y = c_0 + c_1 x$$

then the sum S may be written as

$$S = a + b + c_0 + c_1 x = a + b + x + c_0 + x(c_1 - 1) = S_x + c_0 + x(c_1 - 1)$$

If the last expression is substituted in $32 \leq S_y \leq 34$ we get

$$32 - c_0 - x(c_1 - 1) \leq S \leq 34 - c_0 - x(c_1 - 1)$$

The interval limits are thus dependent on x Twenty five cases were examined in order to find a proper value for x S was less than 34 cm in all these cases The values of y that corresponded to the critical values of 32 cm and 34 cm respectively were calculated from these cases The function then gave the

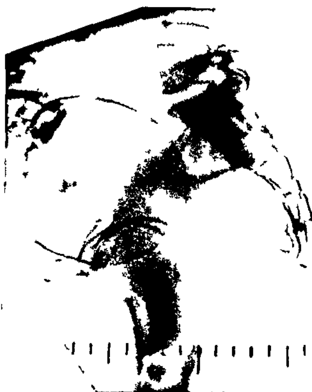


Fig 6 Lateral view of pelvis obtained with patient in position shown in fig 4

distal part of the pelvis could therefore not be used in the present investigation unless the figures of the measurements of the intertuberous diameter as obtained by the two methods were related

According to Borell & Fernström the interval for border line cases is

$$32.0 \leq S \leq 34.0$$

where $S_y = a + b + y$ and a = sagittal diameter of the pelvic outlet (cm), b = interspinous diameter (cm), y = posterior intertuberous diameter (cm)

The interval limits, 32 cm and 34 cm, were calculated from pelvic dimensions in a large number of cases that had been critically studied One purpose of the present investigation was to find an interval valid for $S_x = a + b + x$, where x denotes posterior intertuberous diameter (in cm) determined by the orthodiagraphic pelvimetry method

The intertuberous diameter was therefore determined in 73 cases by both methods, that is (1) according to Chassard Lapiné (y) and (2) from orthodiagraphic projections (x), and the linear relationship between x and y was calculated by the method of least squares The calculation gave

$\bar{x} = 10.85, \bar{y} = 13.48, s^2_x = 0.0322$ $s^2_y = 1.1134$ $\hat{y} = 3.7061 + 0.9000x, s^2 =$ $0.3656, r_{xy} = 0.8232$

ment is carried out with ease and speed and with little discomfort to the patient — there is no need for her to assume an inconvenient and tiring position (3) only one anteroposterior and one lateral view are required to obtain the desired information

For purposes of comparison it may be mentioned that with the method developed by BORELL & FERNSTROM (1960) it is necessary to obtain two a p and two lateral films for the corresponding amount of information Another advantage of orthodiagraphic pelvimetry is that the magnification factor is eliminated Measurements of the two transverse diameters as obtained directly from the film are therefore identical with the true ones

The ischial spines in exceptional cases may be so small that they are concealed by the ischium and are therefore not visible in the obturator foramen The sum of the diameters is in such cases practically always more than 31 5 cm and special measures for a clear demonstration of the interspinous diameter need not be taken

If the anteroposterior view is unsati factory a second film in this projection may be obtained without risk to mother or foetus at least if the latter presents by the vertex the maternal and the foetal gonads receive only 0 0002 r in this projection

The intertuberous diameter may be taken to be the distance between various points on the ischial tuberosities depending on which part of the latter is lowermost on the film The closer these points are to the birth canal the greater is the prognostic value of the corresponding diameter With the tech nique described the endpoints of the intertuberous diameter are probably close to the wall of the birth canal

The distance between the medial aspects of the posterior part of the ischial tuberosities was determined in a few cases of non pregnant women and on a dry pelvis preparation al o by means of the orthodiagraphic method with the beam perpendicular to a plane through the pelvic inlet (Thoms projection) This distance was compared with the intertuberous diameter as obtained from the orthodiagraphic anteroposterior view The measurement in some cases tallied but in others that obtained from Thoms view was slightly smaller than the measurement obtained by the orthodiagraphic method

Orthodiagraphic pelvimetry also permits the determination of the transverse diameter of the pelvic inlet The overcouch tube is u ed with the beam vertical the tube being moved 6 cm to each side of the midline and the light beam diaphragm adjusted so that an area 4 cm by 4 cm is projected onto the film If this view is also to be utilized for the assessment of the size and moulding of the foetal head a omewhat larger area is projected onto the film It should however be borne in mind that a slightly larger error may arise as compared with the determination of the transverse diameters of the outlet if the tube is inaccurately set This is due to the fact that the distance between the film and the transverse diameter (approximately 10 to 12 cm) is somewhat longer than that between the film and the ischial spines (approximately 5 to 7 cm)

Table

Radiation dose to the maternal ovaries with a p view

Position of ionization chamber	Dose calculated in r — mean value (minimum and maximum values)
Right ovary	0 0027 (0 0004 – 0 0107)
Left ovary	0 0034 (0 0003 – 0 0092)
Right ovary at end of pregnancy	0 0002 (0 0001 – 0 0003)
Left ovary at end of pregnancy	0 0002 (0 0001 – 0 0004)

corresponding x values to be inserted in the limited expression (Fig 8) We found $29\ 49 \leq S_x \leq 31\ 72$, or after rounding off to the nearest half centimeters, $29\ 5 \leq S_x \leq 31\ 5$ which is the interval for border line cases when the diameter sum contains a measurement of the posterior intertuberous diameter according to the orthodiagraphic method

The above figures express the interval for the border line cases by the method used in this investigation, and represent a transformation of the interval 32 cm — 34 cm which is the range for the border line cases in Borell & Fernstrom s method This transformation was made in order to be able to use these authors formula for the capacity of the distal part of the pelvis in our orthodiagraphic studies It is hoped that a series of cases examined by orthodiagraphic pelvimetry will eventually be available that is sufficiently large to permit an assessment of the prognostic value of this method as compared with that developed by BORELL & FERNSTROM (1960)

Radiation dose with the present technique The radiation doses to the maternal ovaries and foetal gonads are given in the Table The doses associated with the anteroposterior view were calculated in 8 corpses, with one ionization chamber placed on each ovary and two on the estimated sites of the ovaries at the end of pregnancy Each chamber placed in the true pelvis received about 0 003 r If the foetal head has descended into the true pelvis it may be assumed that it receives the same radiation dose The ovaries at term are at a considerable distance from the irradiated field and then receive only 0 0002 r If the presentation is a vertex one, the foetal gonads receive approximately the same, or a lower dose The radiation dose with the Borell & Fernstrom method is about 20 times higher for the same amount of information

Discussion

Orthodiagraphic pelvimetry is by no means a new method RIBBING used it as early as 1932 to determine the transverse diameter of the pelvic inlet HODGES & NICHOLS (1949) recommended it strongly, but their technique required complicated roentgen apparatus which prevented the method from becoming popular

The orthodiagraphic pelvimetry described in this paper has several advantages (1) conventional roentgen apparatus may be used, (2) the measure

ment is carried out with ease and speed, and with little discomfort to the patient — there is no need for her to assume an inconvenient and tiring position (3) only one anteroposterior and one lateral view are required to obtain the desired information

For purposes of comparison it may be mentioned that with the method developed by BORELL & FERNSTROM (1960), it is necessary to obtain two a p and two lateral films for the corresponding amount of information Another advantage of orthodiagraphic pelvimetry is that the magnification factor is eliminated Measurements of the two transverse diameters as obtained directly from the film are therefore identical with the true ones

The ischial spines in exceptional cases may be so small that they are concealed by the ischium and are therefore not visible in the obturator foramen The sum of the diameters is in such cases practically always more than 31 5 cm and special measures for a clear demonstration of the interspinous diameter need not be taken

If the anteroposterior view is unsatisfactory a second film in this projection may be obtained without risk to mother or foetus at least if the latter presents by the vertex the maternal and the foetal gonads receive only 0 0002 r in this projection

The intertuberous diameter may be taken to be the distance between various points on the ischial tuberosities depending on which part of the latter is lowermost on the film The closer these points are to the birth canal the greater is the prognostic value of the corresponding diameter With the technique described the endpoints of the intertuberous diameter are probably close to the wall of the birth canal

The distance between the medial aspects of the posterior part of the ischial tuberosities was determined in a few cases of non pregnant women and on a dry pelvis preparation also by means of the orthodiagraphic method with the beam perpendicular to a plane through the pelvic inlet (Thoms projection) This distance was compared with the intertuberous diameter as obtained from the orthodiagraphic anteroposterior view The measurement in some cases tallied but in others that obtained from Thoms view was slightly smaller than the measurement obtained by the orthodiagraphic method

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Acknowledgement

We wish to record our indebtedness to S Benner for valuable aid in measuring the radiation dose and to F Carlstrom for the statistics

SUMMARY

A method of orthodiagraphic pelvimetry for the determination of the interspinous and intertuberous diameters is described This may be employed with ease speed and little discomfort to the patient and gives a very small radiation dose to the maternal ovaries and the foetal gonads

ZUSAMMENFASSUNG

Eine orthodiagraphische Methode der Beckenmessung zur Bestimmung des interspinosen und des intertuberosen Durchmessers geeignet wird beschrieben Die Methode ist einfach rasch und bequem fur die Patientinnen die Strahlenmenge in Bezug auf die Ovarien der Mutter und die foetalen Geschlechtsorgane ist gering

RÉSUMÉ

Description d une méthode de pelvimétrie orthodiagraphique pour la mesure des diametres interépineux et intertubérositaire Son utilisation est facile rapide et peu genante pour la patiente et donne de très petites doses de rayonnement aux ovaires maternels et aux gonades foetales

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FROM ROENTGENDIAGNOSTIC DEPARTMENT B (DIRECTOR N P G EDLING) KAROLINSKA SJUKHUSET STOCKHOLM SWEDEN

DYSFIBROPLASIA, DYSCHONDROPLASIA AND DYSOSTEOPLASIA OF BONE

by

NILS P G EDLING

Considerable variations in site of the focal bony *manifestations of hyper parathyroidism* are evident from a perusal of the roentgenologic literature. There is however now no doubt that the disorders in the bones are a result of excess production of parathyroid hormone (Figs 1 and 2a b). The varying lesions, i e cysts osteitis fibrosa or so called giant cell *tumours* according to their appearances and sites all have also essentially the same pathogenesis and when present in hyperparathyroidism are usually not classified as different lesions. It is when these lesions of the bone occur as solitary processes due to some other cause than hyperparathyroidism that they are generally considered as different and *distinct* pathologic entities often with further subdivisions (Fig 2c). They are therefore described in special chapters in the textbooks of pathology and roentgenology.

McWhirter (1952) against this opinion has emphasized the close relationship of these more or less cystic like bone changes to developmental errors at the epiphyseal plates. It is the vascularity of the lesion that basically determines the histologic findings and this in turn is dependent on the time when the error in bone formation took place. A lesion that develops in an epiphyseal

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Acknowledgement

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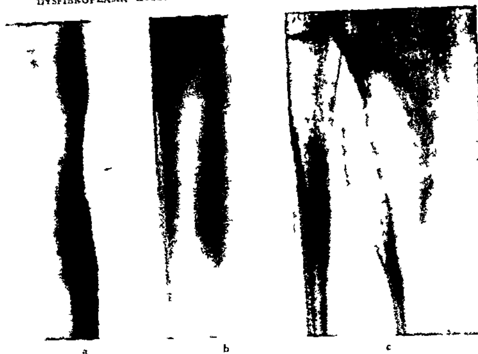


Fig 2 Subperiosteal e panding dysfib opla a a) Hyperparathyroidism Process situated medially in m l p rt of t bial shaft. b) Sam case as in (a) after parathyro dectomy Healing with residual def rmity c) So-c lled aneurysmal bone cyst (biopsy Process s tuated laterally i i pro imal portion of right t bial shaft

Abnormal formation of bone resulting in variations in structure and site may also occur and to be consistent with the above may be called dysosteoplasia These lesions when solitary are described under the heading of exostosis or osteochondroma They are usually found in adult life and are typically situated in the metaphyses of the long bones So-called diaphyseal aclasis (multiple osteochondromas) a hereditary disorder characterized by the presence of multiple exostoses of the long bones is clearly a disturbance of growth

Also the fibro osteomas and osteomas of the skull and facial bones developed in membrane may be included in dysosteoplasia Owing to the similarity of their histologic structure BILLING & RINGERTZ (1946) regard them as one entity HOBAEK (1951) also finds the variations of a quantitative rather than qualitative nature and admits that they are not easily distinguishable However from a clinical standpoint it seems to him reasonable to make a distinction

Despite their different appearances and sites, the dysosteoplastic changes

area, at the time of fusion, usually has a higher degree of vascularity than one that separates from the epiphyseal area as the bone grows in length McWHIRTER proposed the term dysfibroplasia to include these different manifestations of the same pathologic process in the bone BOYD (1944), although not classifying the so called giant cell tumour as a true tumour, somewhat inconsistently compared it with the primary malignant tumours for purposes of clinical differentiation

The more generalized process of the same type is usually called polyostotic fibrous dysplasia and, like the focal manifestations, held as a pathologic entity However, it seems reasonable to accept also these changes as resulting from a disorder of bone formation in epiphyseal plates for a long period of growth This is evidenced by their situation in bones developed in cartilage, and the observation of areas of cartilaginous tissue in the fibrous process by HOBAEK (1951), as described by CODMAN (1931) in so called giant cell tumours Migration of the lesion from the epiphyseal plate is demonstrated in HOBAEK s illustrations (Figs 3 and 4 in his paper)



Fig 1 Expanding dysfibroplasia in hyperparathyroidism a) Process situated in the third metacarpal and proximal phalanx of the left hand b) After parathyroidectomy Healing with new bone formation and decrease of the deformity

Cystic like areas of bone may also be caused by chondromatous changes and, if not calcified, may be impossible to separate roentgenologically from *dysfibroplastic changes It seems reasonable to assume that these* changes may also originate from errors in the complex development of bone at an epiphyseal plate, arrested at the cartilaginous stage instead of continuing to the normal formation of bone The essential cause of the lesion is again suggested to be a disorder in bone formation, as in dysfibroplasia, even if the histologic findings are different A suitable term is dyschondroplasia, if the dyschondroplastic process is calcified, the chondromatous nature is easily identified roentgenologically as the so called calcified enchrondroma The appearances of the calcified ecchrondroma, a lesion usually found in the phalanges, are well known The occurrence of multiple chondromatous areas, as in multiple chondromatosis, may also be explained as disseminated developmental aberrations in bone formation during the period of growth

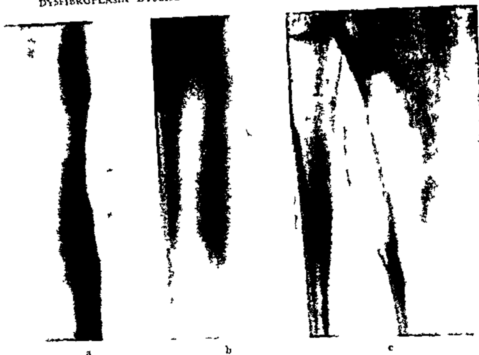


Fig 2 Subperiosteal expanding dysfibroplasia a) Hyperparathyroidism Process situated medially in mid part of tibial shaft b) Same case as in (a) after parathyroidectomy Healing with residual deformity c) So-called aneurysmal bone cyst (biopsy) Process situated laterally in proximal portion of right tibial shaft

Abnormal formation of bone resulting in variations in structure and site, may also occur and to be consistent with the above may be called dysosteoplasia These lesions when solitary are described under the heading of exostosis or osteochondroma They are usually found in adult life and are typically situated in the metaphyses of the long bones So-called diaphyseal aclasis (multiple osteochondromas) a hereditary disorder characterized by the presence of multiple exostoses of the long bones is clearly a disturbance of growth

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Despite their different appearances and sites the dysosteoplastic changes



Fig 3 Subperiosteal expanding dysfibroplasia probably due to trauma Injury to dorsal aspect of the right fifth metacarpal bone due to fall in early life followed by swelling

Fig 4 Dysosteoplasia probably due to trauma Injury in early life deformity of M 4 and M 5 with irregular bone formation in the soft tissues Micro copy after removal of metacarpal together with phalanges highly fibrotic tissue with dilated cavernous vessels no malignancy

Fig 3 Fig 4

may be explained by a disturbance in bone formation, either in the epiphyseal plates or in the centres of ossification in membrane Evidence supporting the conception of a primary affection of bone formation in an epiphyseal plate is the presence of shortening or deformity of the affected bones and the tendency of the dysplastic change to cease when the growing period of the individual has ended The bone changes are associated in some cases with developmental failures in other tissues, for example angiomata

In addition to developmental errors, trauma may also produce aberrations in bone formation, or new bone formation giving rise to clinical features of tumour growth The roentgenologic changes may range from simple cysts to complex outgrowths (Figs 3 and 4) and be impossible to differentiate from similar changes due to other causes Malignancy has been suggested in many of these conditions

It is recognized that a disorder in bone formation may occur when a tissue other than fibrous tissue or cartilage develops instead of new bone (Fig 5) This also constitutes dysplasia of bone, an example of this disorder is hemangiomatous tissue

All changes due to developmental aberration in bone formation are of alike clinical and roentgenologic importance as long as they remain innocent The lesions are not true tumours in the strict sense of the term and there is no definite proof that they are more prone to malignancy than would be expected from any other developmental disorders They do not kill the patient and they do not infiltrate the surrounding tissues, even if expanding When the bone formation is deranged and a tissue other than bone tissue is laid down in the area, this new tissue is completely differentiated and a precise diagnosis of the type of change is therefore often of little practical importance The growths may, however, produce difficulties when they interfere with the

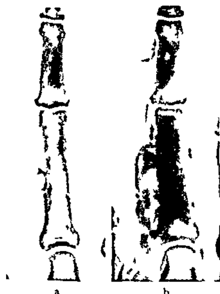


Fig 5 Dysosteopla a of finger due to arterio-venous fi t la (followi g trauma) a) Eccent ic d fects i the phalanges and superfic al new bon format on b) Arteriog aphy Contra t fill ng of a teries with dilated ve s th ough fi t lae the ein occupy the bony d fects

movements of the extremities if they are injured by virtue of their prominence, if fractures occur, or if the lesions are expanding

The limited possibilities of a roentgenologic assessment of the absence or presence of malignancy are well known The main task for the radiologist in doubtful cases is a careful presentation of the different parts of the tumour in order to be able to suggest the right area for biopsy Any of the changes if progressively expanding or if extirpated for any reason should be examined histologically and graded the gradation is most valuable in the assessment of the radiosensitivity of the process and as a guide to the treatment and follow up

The pathologist finds great differences in the gross and histologic examinations of the changes and may therefore need a classification based on his findings The classification should primarily take account of the complex development of the bone with its aberrations and secondly of its appearances A classification may then be of clinical value and not lead to confusion from presenting a large number of clinical pathologic and individual names of no informative value

The absurdity in subdivisions was demonstrated by JAFFE (1958) in the differential diagnosis of bone cysts and so called aneurysmal bone cysts If a solitary bone cyst has become filled with an organizing blood clot in consequence of a fracture its histologic appearances are reminiscent of what is characteristic of an aneurysmal bone cyst The roentgenographic appearances are of crucial importance in their separation the diagnosis depending upon the lesion being either central or eccentric with a 'blow out distension Further the histologic similarity between so called giant cell tumours and so called aneurysmal bone cysts would also appear to be proved by the fact that the identification of the lesion is facilitated by the knowledge of whether it was located in an epiphyseal or metaphyseal area The difference in the appearances in the roentgenogram depends upon the variation in vascularity of the sites in the bone a rich blood supply associated with expansion The difficulty in separating different manifestations of the same lesion is obvious

SUMMARY

Benign disorders in bone formation due to hyperparathyroidism, developmental errors and trauma are discussed. The terms dysfibroplasia, dyschondroplasia and dysosteoplasia are proposed as principal divisions of these conditions.

ZUSAMMENFASSUNG

Die gutartigen Knochenveränderungen bei Hyperaktivität der Nebenschilddrüsen, bei Entwicklungsstörungen und nach Verletzungen werden erörtert. Die Ausdrücke Dysfibroplasie, Dyschondroplasie und Dysosteoplasie werden vorgeschlagen, um die verschiedenen Gruppen dieser Veränderungen zu trennen.

RÉSUMÉ

L'auteur étudie des troubles bénins de la formation osseuse dus à l'hyperparathyroïdie, aux erreurs de développement et aux traumatismes. Il propose, pour les principales division de ces affections, les termes de dysfibroplasie, dyschondroplasie et dysostéoplasie.

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FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR PROF K LINDBLOM) KAROLINSKA SJUKHUSET AND THE DEPARTMENT OF PATERNITY (DIRECTOR DOCENT T ROMANUS) INSTITUTE OF FORENSIC MEDICINE, KAROLINSKA INSTITUTET STOCKHOLM SWEDEN

A VARIATION OF THE ATLAS

Roentgenologic incidence of a bridge over the groove on the atlas for the vertebral artery

by

T ROMANUS and A TOVI

One of the variations displayed by the atlas vertebra is a bridging over (ponticulus) of the sulcus arteria vertebralis (Fig 1) The anomalies of the atlas have apparently not been subjected to exhaustive anatomical and roentgenologic analyses and no description of the histologic formation of the ponticulus has appeared in the current literature

CLELAND (1861) and ALLEN (1879) described the anatomical structure and the homology of the ponticulus in some detail, and an anatomical analysis of the feature was published by TESTUT (1921) SCHINZ in his great 'Lehrbuch der Rontgendiagnostik (1951) referred to the bridge formation as a ligament ossification (Bandverknocherung) without pathologic significance and estimated its incidence to 10 % KOHLER & ZIMMER (1953) gave yet another description of the bridge BELOT & NADEL (1939/40) reported that the sulcus arteria vertebralis may be transformed into a foramen by a lamella of bone extending from the posterior edge of the massa lateralis to the arcus posterior

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Fig. 1. Atlas vertebrae without a ponticulus (left) and with a ponticulus (right).

PANCOAST et coll. (1942) stated: 'There are numerous variations of this foramen. It is found complete, incomplete and sometimes in a more or less fibro osseous condition which might easily be misinterpreted as a fracture or torn periosteum.' HADLEY (1944, 1956) also drew attention to this variation in the structure of the atlas, which he illustrated with excellent roentgenograms. SELBY et coll. (1955) mentioned that this characteristic may possibly be inherited and that the bridging may be partial, total or absent. SELBY claimed that the incidence of such a bridge among adults is 13.6 %. GEJVALL (1960) discovered the ponticulus in 11.4 % of a sample of medieval Swedish skeletal material.

Anatomy. The following account is based mainly on the anatomical textbooks of TESTUT (1921), POIRIER (1911) and CUNNINGHAM (1951).

The atlas consists of two lateral masses united by the anterior and posterior arches (Fig. 1). Each lateral mass is made up of six irregular surfaces consisting of the upper surface (cavitas glenoidalis), the inferior articular facets, the anterior surface, the inner surface, the external surface, and the posterior surface.

The transverse process arises external to and principally from the upper half of the lateral mass by two roots that form the vertebrarterial foramen

The posterior arch arises from the posterior surface of the lateral mass and in part from the posterior root of the transverse process The arch is compressed from above downwards and anteriorly, and bounds a groove that curves around the posterior aspect of the superior articular process the groove is also continuous externally with the vertebrarterial foramen The posterior arch becomes thicker mesially and posteriorly displays a rough irregular projection, the posterior tubercle (tuberculum posterius), which represents the spinous process A small prominant tubercle arising from the posterior extremity of the superior articular process overhangs the groove and not infrequently becomes developed so as to form a bridge of bone (the ponticulus) that converts the groove into a canal (foramen arcuale) (X in Fig 1) The vertebral artery and the first cervical or suboccipital nerve pass through this foramen, a feature encountered in many animals It is noteworthy that the grooves traversed by the two highest spinal nerves lie behind the articular processes and not in front as in other parts of the column

TESTUT mentioned as yet another variation the occurrence of two ponticuli, immediately adjacent to one another and on the same side

POIRIER recorded seeing a ponticulus in which the cranioventral portion was perforated and in 2 cases in a material of 500 cases observed a bony bridge running from the outer rim of the cavitas glenoidalis to the dorsal half of the processus transversus he also stated that in isolated instances he had encountered a ponticulus that was so broad that it extended as far as the medial portion of the dorsal half of the processus transversus to form a canal for the arteria vertebralis

The present authors would mention that a ponticulus may occur either unilaterally or bilaterally

SCHWEGEL (1859) also described different variations in the structure of the sulcus arteria vertebralis He found that the posterior part of the atlas which together with the occipital bone forms the first intervertebral canal was transformed by thin bone lamellae into one two or sometimes three canals If there was only one canal the vertebral artery and vein and the first cervical nerve ordinarily passed through it if there were two canals the lower one was passed by the nerve and the upper by the vessels or the vein was outside the canal In one case the posterior branch of the second cervical nerve, i e the major occipital nerve passed through a vertical canal behind the back shank of the transverse process

Histology There appears to be no clear conception of the histologic structure of a ponticulus and the reports differ A ponticulus is variously interpreted as an ossification of a ligament (SCHINZ 1951) or a bony spicule growing from the posterior edge of the processus articularis superior (SELBY 1955)



Fig 2 Atlas in situ a) Massa lateralis with straight posterior profile (class I) and arcus posterior non eminentia (class 1) b) Massa lateralis with curved posterior profile (class II) and arcus posterior with incipient concavity (class 2) c) Massa lateralis with caudally orientated processus posterior (class III) and eminentia on arcus posterior (class 3) d) Massa lateralis with spinulus anterior (class IV) and arcus posterior with spinulus posterior (class 4)

Preliminary histologic examinations (performed by L Gyllensten) of an atlas vertebra with a ponticulus revealed that the latter is comparable to a processus transversus Both the processus transversus and the ponticulus display peripherally a thin corticalis, composed prepominantly of basic lamellar systems with occasional Haversian systems and also a transition from the more compact corticalis into a central spongiosa The ponticulus, however, has a thinner corticalis with a more irregular arrangement of the lamellae, while its spongiosa is more strongly developed These histologic investigations enable no conclusions to be drawn about possible differences in the bone forming processes between the processus transversus and ponticulus

The histologic genesis of a ponticulus will be dealt with in more detail in a forthcoming report based on autopsy material

Material, methods and classification An investigation of a collection of roentgenologic material which is described below, and of atlas vertebrae from GEJVALL's sample of medieval skeletal material from Westerhus, suggest the



Fig 3 Atlas in situ a) Unilateral ponticulus (class V 5) b) Ponticulus on both sides (class V 5)

following classification which on a future occasion will be tested against a familial study This classification however should only be considered as provisional

Those variations that may arise in the posterior edge of the massa lateralis are designated with roman numerals I to IV and those occurring in the arcus posterior are given arabian numerals 1 to 4 The final classification of each individual atlas is arrived at by taking the higher value roman and arabic in each series Thus if one side is I 4 and the other II 2 the final classification becomes II 4

Posterior edge of massa lateralis

I — Massa with straight posterior profile (Fig 2a)

II — Posterior profile curved dorsally concave and without a change in direction united with the cavitas glenoidalis to form a pointed or rounded corner termed the processus posterior (Fig 2b)

III — Processus posterior orientated caudally (Fig 2c)

IV — Prominent processus posterior coming closer to the arcus posterior than in class III but not reaching it This formation is here termed the spinulus anterior (Fig 2d)

Arcus posterior

1 An arcus posterior that swings up either abruptly or not at all non eminentia no protuberance in this part of the sulcus a vertebralis (Fig 2a)

2 Arcus posterior with a concavity orientated cranially throughout 'non eminentia (Fig 2b)

3 Eminentia A protuberance ventrally from the upper tip of the triangle formed in the most dorsal part of arcus posterior, this triangle is evident only



Fig 4 Atlas vertebra from the Anatomic Institute of Karolinska Institutet Ponticulus on both sides (class V 5) (cf fig 3) The ponticulus and the processus transversus of this vertebra were examined histologically

in roentgenograms and corresponds to the tuberculum posterior of the atlas vertebra (Fig 2c)

4 *Spinulus posterior analogous by criteria to those for the spinulus anterior* (Fig 2d)

In addition, a ponticulus is classified as V, 5, and it is noted whether it is uni or bilateral (Fig 3)

It should be pointed out that it may be difficult to distinguish in a roentgenogram, especially in an oblique view, between III and IV in this classification The same applies to the arcus posterior, classes 1 and 2, and 3 and 4, respectively The sample has yielded no examples of a spinulus posterior (class 4) that were as long as a spinulus anterior (class IV) Since the above mentioned collection was investigated, a case of a very large spinulus posterior has been encountered

The material comprised 105 cases taken at random and not selectively, and represented 54 males between the ages of 12 and 75 years ($M \pm \varepsilon(M) = 40.8 \pm 2.1$ years, $\sigma = 15.2$ years), and 51 females between 9 and 80 years of age ($M \pm \varepsilon(M) = 40.0 \pm 2.3$ years $\sigma = 16.2$ years)

The demonstration of the variation demands a true lateral view of the atlas, with the neck extended and the head flexed as much as possible This posture considerably increases the distance between the arcus posterior atlantis and the os occipitale and prevents the latter from obscuring the small area in which the variation occurs A lateral view is also essential if the posterior profile of the massa lateralis and the cranial surface of the arcus posterior are to be shown An attempt was made in certain cases with a complete foramen to define this in frontal views, without tomography, but this proved unsatisfactory

Oblique views have been particularly valuable in cases in which the ponticulus occurred bilaterally or in those types falling within the classification In such cases the head was turned in a suitable direction under fluoroscopic control

The processus mastoideus projected into this area in a small proportion of cases and necessitated tomography The possibilities offered by stereoscopy in assessing the lateral localization were investigated but with indefinite results

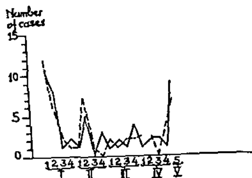


Diagram 1 Totals of males and females in the different groups ——— Males (number of cases = 54) — — — Females (number of cases = 51)

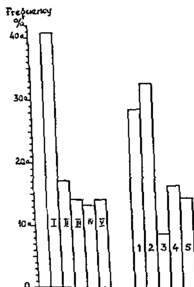


Diagram 2 Percentage distribution (males plus females) in the different classes

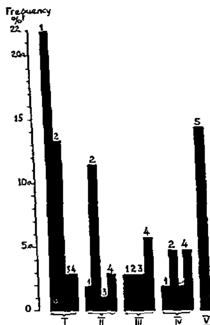


Diagram 3 Comparison of the percentage distribution (males plus females) in the different classes

The material has been divided according to the scheme and the distribution of the variation in males and females is evident from Diagram 1 The percentage incidence of each of the different classes are shown in Diagram 2 and a comparison of the percentage distribution of the various classes in Diagram 3 The massa lateralis presents a straight posterior profile in 41 % of cases (class I) whereas 17 2 % have a curved posterior profile (class II), 14 4 % a caudally

orientated processus posterior (class III), and 13.2 % a spinulus anterior (class IV). The equivalent values for the arcus posterior are: class 1, i.e. with *no suggestion of concavity*, and class 2, with incipient cranially orientated concavity, about 30 % each; the smallest group is class 3, with an eminentia, with an incidence of 8.7 %, while a spinulus posterior occurs in 16.3 % of the sample. Finally, a ponticulus (class V, 5) has a frequency of 14.3 ± 3.4 %, i.e. it occurs in 15 out of 105 cases.

The 15 subjects with a ponticulus comprised 9 males and 6 females. The proportion of males with this feature amounted to 16.7 ± 5.1 %, with a corresponding figure of 11.8 ± 1.5 % for females. The difference between males and females with a ponticulus was 4.9 ± 6.8 %. The variability between males and females was not significant (0.40 < P < 0.50). There was also *no obvious relationship between the age of the subject and the different classes.*

It was noted that a ponticulus occurred unilaterally in 6 and bilaterally in 3 males but was present unilaterally in 3 and bilaterally in 3 females.

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Added in the proofs

Since this paper was submitted, an article of great interest (PYO & LOWMAN 1959) has come to the knowledge of the present authors.

SUMMARY

A roentgenologic study of the atlas vertebra in a material of 105 cases revealed a ponticulus in 15 cases (14.3 %), in 6 of which the condition was bilateral and in 9 unilateral. A method of classification based on the different recognized types of this variation is suggested.

ZUSAMMENFASSUNG

Eine röntgenologische Studie von Atlaswirbeln in 105 Fällen zeigte einen Ponticulus in 15 Fällen (14.3 %). 6 Fälle zeigten ihn beiderseitig und 9 Fälle einseitig. Ein Klassifikationsschema für die verschiedenen bekannten Typen dieser Variation wird vorgeschlagen.

RÉSUMÉ

L'étude radiologique de l'atlas dans une série de 105 cas a montré dans 15 cas (14.3 %) la présence d'un petit pont: des deux côtés dans 6 cas et d'un seul côté dans 9 cas. *Les auteurs* proposent une méthode de classification basée sur les différents types de cette variation.

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CONGENITAL APLASIA OF THE ABDOMINAL MUSCLES WITH UROGENITAL MALFORMATIONS

by

LARS ANDRÉN, LARS BJERSING and JAN LAGERGREN

Congenital aplasia of the abdominal muscles is part of a syndrome with other malformations, particularly of the urogenital tract The complete syndrome was first described by PARKER (1895) The first compilation of cases on record was published by HOUSDEN (1934), and further collections have since been presented by SILVERMAN & HUANG (1950), METRICK et coll (1957), LATTIMER (1958), BEGG (1959), MONNET et coll (1959), and others

Some 100 cases have so far been reported The most common findings are (1) total or partial absence of the abdominal musculature and broadening of the lower chest, (2) dilated and hypertrophic urinary bladder, hydroureters, and hydronephrosis, (3) non descent of the testicles, and (4) malrotation of the intestine

Other, though less common, findings are persistent urachus, dislocation of the hip, club foot, harelip, spina bifida, hydrocephalus and malformations of the heart The most conspicuous sign, demonstrable immediately after parturition, is the distended abdomen with wrinkled skin The intra abdominal organs, particularly the widened ureters and the hypertrophic and dilated urinary

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Fig 1 General view of abdomen

bladder which is usually adherent to the umbilicus or anterior wall of the abdomen are readily palpated through the thin abdominal wall through which intestinal peristalsis may often be discerned When the child is placed on its back the flanks bulge out with flattening of the abdomen

Case report

A boy born at full term the first child of a 21 year old mother who had previously had one abortion (mens III) The lower chest was broad and prominent and the abdomen showed large loose vertical and horizontal wrinkles The abdominal contents tended to spread to both sides (Fig 1) and were easily palpable through the thin abdominal wall cystic lumps could be palpated in the lower lateral segment The testes were undescended On massage of the area between the symphysis and the umbilicus a strong stream of urine flowed from the urethra at the same time as a firm rounded body extending from the symphysis to the area immediately to the right of the umbilicus and apparently adherent to the abdominal wall contracted (Fig 2a)

The child s general condition was initially good and the urinary output satisfactory The steroid pattern of the urine was normal The N P N during the first few weeks varied between 30 and 50 mg/100 ml and in the 5th week rose to 176 mg/100 ml Ureterocystography (via a plastic catheter in the urethra) revealed an enlarged bladder with a broad urachus up to the level of the umbilicus and marked widening of the upper part of the urethra during micturition with filling of a 1 cm long utriculus prostaticus (Fig 2b) After micturition the upper part



a b

Fig 2 a) Frontal view during micturition enlarged urachus b) Lateral view during micturition distension of upper part of urethra with large prostatic utricle

of the urethra was still somewhat widened (Fig 3a) Pyelography with direct puncture of the left renal pelvis and of the distal part of the right ureter via the abdominal wall demonstrated wide tortuous ureters and distended renal pelves particularly on the right side (Fig 3b) The ureters did not empty into the bladder Bilateral ureterostomy with insertion of a T tube was followed by good output from the right side but only a minimal flow from the left A few days after the operation the N P N fell rapidly the child gradually became worse and died on the 7th day it was then 6 weeks old

Autopsy The abdominal wall was thin The small intestine ascending colon and descending colon had a common long mesentery with a short root attached to the posterior upper left part of the abdominal cavity

The urinary bladder continued up towards the umbilicus in the form of a bluntly terminating persistent urachus The trigone was large and signs of an annular stricture were evident at the site of the ureteric orifice the lower angle of the trigone contained a prostatic utricle over 1 cm long Sparse small tubular glands were seen in several sections cut at different levels through the urethra and the large utricle some of these also showed tubulo alveolar glands emptying partly into the seminal colliculus and partly into adjacent mucosa in the urethra A fair amount of smooth muscle was found in the deeper layers

No narrowing of the lumen of the urethra was demonstrable The ureters were tortuous and wide Gonads resembling testes lay above the pelvis In the right as well as the left ureteric orifice was a polypoid formation a few millimetres long and a few millimetres thick these formations evidently produced considerable narrowing of the lumen of the ureteric orifices



a b

Fig 3 a) Lateral view after micturition upper part of urethra filled but now less distended partial filling of prostatic utricle b) Frontal view of renal pelves and ureters

The left kidney was extremely small and consisted of a thin shell of pale grey brown tissue The right kidney was in a better state and presented evidence of foetal lobation The remaining organs were normal

Histologic findings Sections of specimens from several parts of the abdominal wall were studied Only one showed small rests of striated muscle the abdominal wall consisting solely of normal skin and fibrous tissue of fascia like character in the others

The wall of the urachus contained abundant musculature with moderate fibrosis particularly in the submucosa The mucosa of the urinary bladder was oedematous The polypoid formation in the ureteric orifices consisted of fibrous tissue containing some smooth muscles and a number of wide blood filled vessels The gonads had an ordinary testicular structure and all the tissue studied contained male sex chromatin

Discussion

IKEDA & STOLSSER (1927) assumed that the syndrome was due to some unknown factor that attacks the foetus during embryonic life A number of later authors (FORMIGGINI 1950 SANSONE & SARDINI 1954) shared this opinion This explanation appears most plausible in those cases with not only abdominal muscle aplasia and malformation of the urinary tract but also with e g dislocation of the hip clubfoot spina bifida hydrocephalus malformations of the heart

OSLER (1901) was the first to suggest the possibility that the absence of the normal support of the urinary bladder by the abdominal muscles during foetal life may result in the bladder distending instead of emptying in the normal way HALL (1907) also believed that abdominal muscle aplasia is the primary factor Since the report of a case of abdominal muscle deficiency in association with Hirschsprung s disease (BLASI 1927) the possibility of neuromuscular imbalance

had been discussed as a cause of abdominal muscle deficiency with uropathy (e g DAUT et coll 1947, HENLEY & HYMAN 1953, GREENE et coll 1952)

GUTHRIE (1896) pointed out that the urinary bladder, whose upper part is often adherent to the umbilicus or anterior abdominal wall, is prevented from normally contracting downwards and is thus unable to empty completely This is thought to result in hypertrophy of the bladder with accumulation of urine and dilatation, and finally to retention of urine in the ureters Another theory put forward for the first time by STUMME (1903) assumed ureteric obstruction to be the primary cause

The abdominal muscles are laid down about the fifth week of embryonic life, excretion of urine, however, does not begin until about the ninth week It may therefore be concluded that if abdominal muscle deficiency is related to an obstruction of the lower urinary tract, aplasia must be a secondary phenomenon due either to the direct pressure or indirect pressure which, owing to circulatory disorders, is produced by the distended urinary pathways (STUMME 1903, HOUSDEN 1934)

It should be mentioned in this connection that obstructive uropathy is by no means always associated with abdominal muscle deficiency One of the reasons why the theory of urethral obstruction as the primary cause has not been generally accepted is probably that in most cases no mechanical obstruction could be demonstrated — with the exception of the series studied by HENLEY & HYMAN (1953) in which urethral obstruction was demonstrated in 2 of 3 cases and by LATTIMER (1959) in 17 of 22 cases A possible explanation why urethral obstruction is not found more often is that most of the cases have been examined cystographically with insertion of the catheter via the urethra into the bladder and the possible rupture of membranous urethral valves Another suggestion why no obstruction could be demonstrated in most of the cases has been put forward by BEGG (1959) He expressed the view that in these children the urinary pathways are extremely dilated before birth and that this in turn results in maximal distension of the abdomen, which interferes with normal delivery, during delivery the intraabdominal and the intravesical pressure rise to such an extent as to overcome the urethral obstruction This results in emptying of the bladder and may help to explain the wrinkled, loose appearance of the skin of the abdomen after parturition

The syndrome appears to be almost limited to males The few cases in females included in the collections on record had not the typical combination of abdominal muscle aplasia and uropathy, or if so, it seemed to be less marked

That the testes are undescended is, according to almost all authors, due to the distended bladder together with the dilatated ureters preventing the testes from reaching the vaginal processus The occurrence of malrotation of the intestine has also been explained by the malformations of the urinary pathways But no common satisfactory explanation for the complete syndrome has hitherto been put forward

A search of the literature, however revealed some experimental observations possibly capable of shedding new light on the syndrome Thus GARDNER (1935 1936) found the injection of large amounts of oestrogens into mice to be followed by a marked dilatation of the urinary bladder and sometimes by hydroureter and hydronephrosis and dilatation of the urethra down to the level of the symphysis as well as by scrotal hernia In animals treated in this way before the testes had descended the latter remained undescended These findings were later confirmed by CRELIN & LEVIN (1955)

The syndrome is also essentially analogous to that which occurs in pregnant women During pregnancy the urinary pathways become dilatated and this dilatation occurs so early that there is no reason to assume only mechanical compression of the ureters (OLSSON 1962) It appears that an elongation of the mesentery occurs in pregnancy and thereby allows upward displacement of the intestines It is doubtful whether the dilatation of the abdominal wall can be explained solely by the distension of the uterus for it also occurs in pseudocyesis

In view of observations made in animal experiments and the similarity with the physiologic changes of pregnancy the syndrome might be considered to be due to an abnormal effect of oestrogens on the foetus, which lacks the normal protective mechanism against them According to this line of thought the dilatation of the abdominal wall would be the primary change with consequent aplasia of the abdominal musculature Malrotation of the intestine would then be due to elongation of the mesentery Both dilatation of the urinary tract and failure of the testes to descend are findings corresponding to those made in animals treated with large doses of oestrogens

SUMMARY

A case of congenital aplasia of the abdominal muscles with urogenital malformations is described in detail It is tentatively suggested that the condition may be due to an abnormal effect of oestrogens on the foetus

ZUSAMMENFASSUNG

Ein Fall von angeborener Aplasie der Bauchmuskeln kombiniert mit urogenitalen Missbildungen wird detailiert beschrieben Die Möglichkeit dass die Ursache in abnormaler Oestrogeneinwirkung auf den Foetus zu suchen ist wird erwogen

RÉSUMÉ

Les auteurs décrivent en détail un cas d aplasie congénitale des muscles abdominaux avec malformations urogénitales Les auteurs émettent l hypothese que ces malformations peuvent être dues a un effet anormal des oestrogenes sur le foetus

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URETHROGRAPHIC STUDIES OF THE POSTERIOR URETHRA

II Emptying of the prostatic urethra

by

OLALLO MORALES STIG NILSSON and RAGNAR ROMANUS

It may be convenient first to give a brief recapitulation of certain anatomical details and the terminology used

The most proximal part of the posterior urethra lies intramurally and its length equals the thickness of the bladder wall The mucosal pattern of the prostatic urethra is dominated by the urethral crest in its posterior wall this starts proximally in the intramural part of the urethra and its uppermost portion in the internal urethral orifice is frequently termed the uvula The urethral crest becomes less marked just proximal to the verumontanum (the seminal colliculus) and distally from here continues to the diaphragmatic part of the urethra where it again increases a little in prominence In some instances one or two fine supracollicular mucosal folds (frenulae) from each side of the crest converge down towards the upper pole of the verumontanum

The middle and widest part of the posterior urethra is known as the prostatic sinus The verumontanum bulging from the posterior wall in this region results in the formation of the so-called prostatic sulci at its sides The verumontanum with the openings of the prostatic

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Fig 1 The intramural part of the urethra lies between the bladder mucous membrane in the internal urethral orifice (marked as the distal part of the vesical contrast band) and the upper portion of the prostatic urethra (the upper limit of the prostatic sulci distended by chronic prostatic inflammation) a) Injection film b) emptying film A band of poor contrast caused by the contracted sphincter nudae muscle is evident in the proximal part of the urethral bulb in the latter (See MORALES & ROMANUS ref 25)

Fig 2 A case of protracted chronic prostatovesiculitis The posterior urethra is distended and the right ejaculatory duct and part of the seminal vesicle and ampulla are contrast filled contraction of the pelvic floor leads to less extensive emptying of the prostatic urethra than usual a) Injection film b) contraction film

utricle centrally and the ejaculatory ducts laterally may vary in size appearance and position The slightly distended segment of the urethra (cranial to the upper portion of the verumontanum) we elect to term the supracollicular sinus The micturition funnel or bladder neck is the portion of the supracollicular urethra (including the intramural part) that widens into a funnel on micturition

Voluntary contraction of the pelvic floor leads to elevation of the pelvic organs (see part I published earlier) and at the same time the content of the posterior urethra is emptied into the urinary bladder This evacuation may be attributed to reflex contraction of the smooth prostatic muscles secondary to voluntary contraction of the pelvic floor and the external sphincter (discussed in further detail in this paper) Slower spontaneous emptying of the posterior urethra does however occur without any initial voluntary contraction of the pelvic floor although this evacuation is less uniform as regards both duration and magnitude (see part I p 85)

Roentgen diagnosis of inflammatory or postinflammatory disorders of the male adnexal glands has hitherto been based upon advanced lesions of the urethra, such as strictures, prostatic calculi or cavities or upon definite displacement of the urethra However, the view has been expressed earlier (MORALES & ROMANUS (ref 24), ROMANUS (ref 34)) that close study of the mucosal pattern of the posterior urethra may be of great value in certain instances

Table

Distribution of cases according to the emptying ability of the prostatic urethra on voluntary contraction of the pelvic floor — if more than one diagnosis was recorded in the same case they were classified as main and secondary the latter diagnosis being shown in parentheses

Diagnosis	Number of cases	Emptying ability		
		More complete	Normal	Less complete
Acute exacerbation of chronic prostato-vesiculitis	15 (5)	14 (1)	1 (2)	(2)
Chronic prostato-vesiculitis	14 (14)	1 (2)	7 (9)	6 (3)
Tuberculous prostato-vesiculitis	1		1	
Prostatic adenomatous hypertrophy	4 (9)	(2)	4 (6)	(1)
Prostatic carcinoma				
Not treated with hormones	3		1	2
Treated with hormones	13	3	8	2
Stricture of the urethra	4 (17)	1 (5)	2 (10)	1 (2)
Normal	2		2	
Total	56 (45)	19 (10)	26 (27)	11 (8)

Demonstration of the mucosal pattern calls for a contrast medium that adheres to the mucous membrane and at the same time distends the urethral lumen The preparation must in other words be water soluble and viscous as for instance Umbradil Viscous U (MORALES & ROMANUS (ref 24)) Similar studies may however be performed with low viscosity media if their concentration is sufficiently high to permit demonstration of the mucosal relief The rate of flow must be fairly high during the injection of a low viscosity medium if the lumen is to be distended sufficiently for the demonstration of narrowed regions e g between adenomas of the prostate If the contrast concentration is too great details of the mucosal relief may be overlooked Furthermore a contrast preparation of low viscosity drains away completely and immediately from the posterior urethra when the injection is interrupted affording no opportunity of comparing films exposed during injection and evacuation

The series studied and the technique employed have been described in earlier publications (references 24 25 and part I of this paper)

The Table gives data on the extent of the emptying of the prostatic urethra in cases of nonspecific adnexal inflammation benign hypertrophy and carcinoma of the prostate If more than one diagnosis was recorded in the same case it was classified as main and secondary the latter diagnosis being shown in parentheses in the table As may be observed emptying of the posterior urethra is quicker and more complete than usual in exacerbations of chronic inflammatory disorders of the adnexal glands (prostato vesiculitis) On the other hand, it is normal or decreased (less complete) in chronic prostato vesiculitis

The emptying was more complete than usual in 29 of 101 cases in 15 of these 29 cases signs of an acute inflammatory process in the adnexal gland co existed with evidence of a chronic condition Three of the cases were of purely chronic inflammatory lesions that is, the case records contained nothing suggestive of exacerbation The main condition in one of these three cases was however prostatic carcinoma and in another sequelae of abdomino sacral rec-

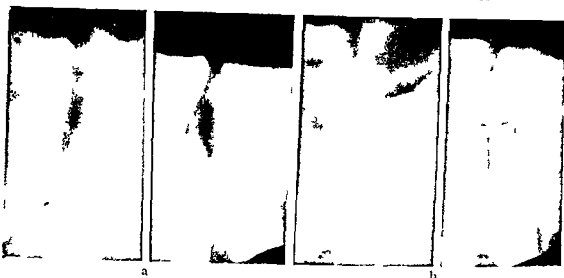


Fig 3 The emptying of the posterior urethra is more complete than usual in an acute exacerbation of chronic prostato vesiculitis a) Injection films b) contraction films

tal excision for carcinoma were present Of the 53 cases in which the emptying was assessed as normal, 16 were of chronic prostato vesiculitis without evidence of exacerbation, while 3 had signs of acute exacerbation Among the 19 cases in which emptying was less complete than usual 9 were of chronic inflammation without signs of activation

Of the 16 cases of prostatic carcinoma, 13 of which received hormonal therapy, 3 (all treated with hormones) showed better emptying than usual, 9 (one before and 8 during hormonal therapy) showed the usual emptying, and in 4 cases (2 before and 2 during hormonal treatment) the emptying was less complete than usual Three cases in which the emptying was more complete than usual had thus all been treated with hormones, of 4 cases in which the emptying was less complete than normal 2 were not treated with hormones, and among the remaining 9 cases in which the emptying was assessed as normal 8 cases were treated with hormones

The following illustrations exemplify the above conditions In pure chronic prostato vesiculitis, contraction ability is reduced and emptying incomplete (Fig 2)

In exacerbations of chronic prostato vesiculitis, emptying is more complete than usual (Fig 3)

In adenomatous hypertrophy, neither the mucosa nor the musculature is infiltrated and emptying is 'normal (Fig 7, part I)

In prostatic carcinoma invading the urethral wall or adjacent structures, the normal emptying capacity is impaired or absent (Fig 8, in part I), but may be restored in some measure following hormonal therapy (Figs 4 and 5)

Effect of voluntary muscular contraction upon the posterior urethra LENDORF (ref 20) as early as 1912 observed on urethroscopy during irrigation that the lumen of

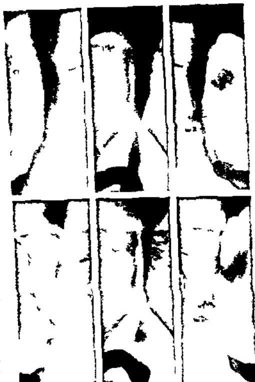


Fig 4 The dilatation of the urethral lumen during injection may bear a relationship to the regression of carcinoma and decrease in prostatic size following estrogen therapy (estrogen atrophy) The malignant infiltration of smooth musculature diminishes and the emptying power of the posterior urethra improves Irregular infiltration of the mucosa persists in the region of the internal urethral orifice Upper row Injection films Lower row contraction films The sphincter nudae muscle in the latter presents a distinct abrupt upper margin The pyramidal shape of the pars nuda is well demonstrated

the posterior urethra decreased in calibre on voluntary contraction of the perineal musculature including the anal sphincter and the external urethral sphincter This constriction took place chiefly by displacement of the urethral walls towards the centre of the lumen It was most marked in the posterior wall less so in the lateral and almost absent in the anterior wall of the prostatic urethra, as a result the urethral lumen in this region assumed in cross section a crescentic shape This author expressed the view that the mural movements were brought about by the intrinsic musculature of the prostate since this musculature is not so marked at the level of the verumontanum where it is least developed He believed this motility to be governed by the contraction of the striated perineal musculature

The motility of the posterior urethra in different conditions has hitherto been studied mainly by means of urethroscopy LENDORF (ref 20) and PRETORIUS (ref 32) using that method found inflammatory and other lesions of the prostate to lead to a decrease in the motility of the corresponding segment of the urethral wall This they observed to affect micturition although the lumen was not truly constricted but showed what are known as wide strictures (Figs 6 and 2)

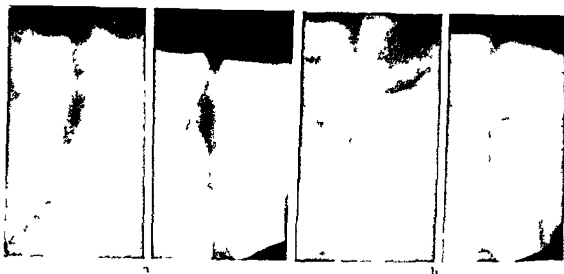


Fig. 3. The emptying of the posterior urethra is more complete than usual in an acute exacerbation of chronic prostato-vesiculitis. a) Injection films. b) contraction films.

tal excision for carcinoma were present. Of the 53 cases in which the emptying was assessed as normal, 16 were of chronic prostato-vesiculitis without evidence of exacerbation, while 3 had signs of acute exacerbation. Among the 19 cases in which emptying was less complete than usual 9 were of chronic inflammation without signs of activation.

Of the 16 cases of prostatic carcinoma, 13 of which received hormonal therapy, 3 (all treated with hormones) showed better emptying than usual, 9 (one before and 8 during hormonal therapy) showed the usual emptying, and in 4 cases (2 before and 2 during hormonal treatment) the emptying was less complete than usual. Three cases in which the emptying was more complete than usual had thus all been treated with hormones, of 4 cases in which the emptying was less complete than normal 2 were not treated with hormones, and among the remaining 9 cases in which the emptying was assessed as normal 8 cases were treated with hormones.

The following illustrations exemplify the above conditions. In pure chronic *prostato-vesiculitis, contraction ability is reduced and emptying incomplete* (Fig. 2).

In exacerbations of chronic prostato-vesiculitis, emptying is more complete than usual (Fig. 3).

In adenomatous hypertrophy, neither the mucosa nor the musculature is infiltrated and emptying is 'normal' (Fig. 7, part I).

In prostatic carcinoma invading the urethral wall or adjacent structures, the normal emptying capacity is impaired or absent (Fig. 8, in part I), but may be restored in some measure following hormonal therapy (Figs. 4 and 5).

Effect of voluntary muscular contraction upon the posterior urethra. Lendorf (ref. 20) as early as 1912 observed on urethroscopy during irrigation that the lumen of



Fig 6 The urethral walls are more rigid and the emptying therefore less extensive than u ual in pure chron c prostato- esicul tis In the presence of fibros s of the prostatic parenchyma the lumen of the posterior u ethra is distended more than normal during injection (see also Fig 1) Three films from the left injection films and the remain ng three contract on films

several cases at sterilization operations in men (vasectomy) in order to study in closer detail the emptying of the posterior urethra The media were iodized oil and viscous or low viscosity contrast media normally employed for urography Despite variations in the irritation of the mucosa by the different preparations and the posture of the patient (supine or erect) the fluid spread uniformly in the supracollicular urethra and vanished rapidly into the bladder after it had been collected for a short while in the prostatic sulci and supracollicular sinus at the upper portion of the verumontanum (Fig 8) The urethra was not dis tended to any noteworthy degree even when the injection was performed rapid ly

These experiments revealed furthermore that the urge to urinate is not ex perienced until the detrusor contracts The sensation was found to be wholly independent of the presence or absence of fluid in the posterior urethra, as also of the irritative action (if any) of the contrast preparation Nor was any differ ence noted when the bladder contained urine or only contrast medium It was the volume of the bladder contents and the rate at which that volume increased together with the accompanying stretching of the bladder wall which appeared to be decisive as has also been pointed out by e g JEFFCOATE & ROBERTS (ref 14) and ROBERTS (ref 33)

When the volume of the bladder contents was fairly small the rapid injec tion of a relatively large quantity of fluid (10 to 15 ml) via the vas deferens to the bladder in several instances elicited detrusor contraction This was how ever of very brief duration and on being asked the patient stated that no urgency of micturition was experienced The greater the volume of the bladder contents the more readily this detrusor contraction occurred until finally it was initiated by a very slow injection of a small quantity of fluid via the vas



Fig 5 Case of estrogen atrophy following hormonal therapy for prostatic carcinoma the urethral lumen is fairly wide and the emptying good a) Injection film b) contraction film A stricture is evident at the site of the contracted sphincter nudae muscle (b) (Cf Fig 1) The arrows indicate the urogenital diaphragm

Voluntary muscular contraction is not, however, the only factor initiating this motility, as the present writers found in experiments performed at vasotomy in which contrast material was injected via the vas deferens, the ampulla, the seminal vesicle and the ejaculatory duct to the posterior urethra (see under next heading) In these experiments, as on active contraction of the pelvic floor, the contrast medium was emptied upwards into the urinary bladder, despite the fact that no contraction of the external sphincter, the perineal musculature, or the levatores ani muscles was observed It would therefore appear that this emptying of medium is due to a spontaneous contraction or rise in tone of the smooth muscles surrounding the posterior urethra This assumption *is further borne out by the observation that cavities situated centrally* in the prostate are better emptied than those more in the periphery of the organ Cavities of this type were seen to be affected in that manner in 16 of the present cases Their shape altered in 3 cases without any distinct emptying of contrast medium, while in 13 cases the quantity of medium decreased irrespective of whether the cavities were of a postinflammatory or postoperative (one case) nature (Fig 7)

Vaso vesiculography used for studying the function of the posterior urethra and the bladder Contrast medium was injected via the divided vas deferens and the ampulla, seminal vesicle and ejaculatory duct to the prostatic urethra and bladder in



Fig 8 Contrast material (iodized oil) injected via the vas deferens to the ampulla and seminal vesicle ejaculatory duct and posterior urethra The fluid collects in the proximal portion of the prostatic sinus and the supracollicular sinus but does not pass down through the infracollicular part The medium is then propelled up into the urinary bladder via the supracollicular urethra both spontaneously and on voluntary contraction of the pelvic floor A drop remains for a moment in the funnel formed by the bladder mucosa at the internal orifice of the urethra before running down the declivity into the bladder a) Injection film b) contraction film

In one case however the contrast medium did pass distally through the diaphragmatic urethra to the back part of the anterior urethra during injection via the vas deferens In this 78-year-old patient who had for a considerable period been treated with an indwelling catheter for large prostatic adenomas with micturition difficulty but no incontinence and in whom signs of malignancy were absent the function of the external sphincter on motility examination was found to be normal During a forceful injection of contrast medium via the vas deferens the patient reported a sensation resembling that of seminal emission or ejaculation and slight erection occurred The contrast medium was then seen to advance distally past the diaphragmatic urethra to the bulbous portion of the anterior urethra The passage of medium through the external sphincter agrees well with the concept that the tone of the internal sphincter increases while that of the external sphincter and detrusor decreases during erection (LANGWORTHY KOLB & LEWIS (ref 19) MAC ALPINE (ref 23))

The morning bladder urine in the male usually contains products from the prostate (as acid phosphatase) and frequently even spermatozoa from the ampullae and seminal vesicles This transport of substances to the bladder is fully accounted for by our observation that fluid entering the posterior urethra from the seminal vesicles and ampullae is propelled by muscular tone into the blad

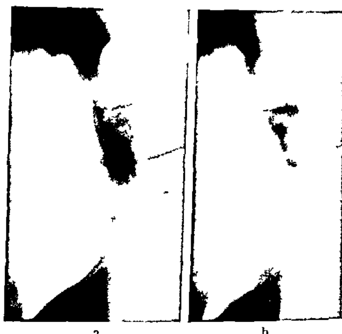


Fig 7 Case of chronic prostatovesiculitis with large cavities that have been opened into the urethra The emptying of the central cavities is more complete than that of those situated further peripherally on contraction of the prostatic smooth musculature after voluntary contraction of the pelvic floor and the external sphincter a) Injection film b) contraction film

deferens The contraction was then of longer duration than that elicited by the rapid injection of a small quantity, and the patient experienced an urge to micturate Fluoroscopy showed an accompanying rhythmic, funnel like widening of the proximal part of the posterior urethra (as if the structures constituting the 'bladder neck' were retracted by the detrusor, most markedly dorsally, less so laterally, and not at all anteriorly) As the widening occurred, contrast medium was seen to enter the proximal portion of the urethra (the 'bladder neck' or micturition funnel')

It would therefore appear that urgency of micturition is related to the degree and duration of the detrusor contraction and is not dependent upon the presence or absence of more or less locally irritative fluid in the proximal segment of the posterior urethra Fluid in the posterior urethra gives rise, instead, to an unconscious contraction of surrounding smooth muscle which propels it proximally into the urinary bladder

These observations agree fully with the absence of urgency of micturition on retrograde urethrography (with or without anaesthesia) even when the posterior urethra is greatly distended The urge to urinate is not felt until the detrusor is contracted

Clinically, this corresponds with the lack of urgency of micturition in women with stress incontinence, although urine enters and even passes through the urethra (cf part I) The same is true in prostatectomized men, in whom a persisting supracollicular postoperative cavity may constantly contain urine without the patient experiencing urgency — until the detrusor is contracted

The fluid injected on vaso vesiculography passed proximally into the bladder but not distally past the external sphincter out into the anterior urethra



F g 8 Contrast material (iod ed oil) inj cted via the a deferens to the ampulla and seminal vesicle ejaculatory duct and posterior urethra The flu d coll cts in the prox mal portion of the prostatic sinus and the sup acollicular s nus but does not pass down th ough the in f acollicular part The medium is then propelled up into the urinary bladder via the supracoll cular urethra both spontaneously and on vol ntary contract on of the pelvic floor A drop remains for a moment in the funnel formed by the bladder mucosa at the internal orif ce of the u ethra before running down the declivity into the bladder a) In ject on film b) contraction film

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der This is further augmented by the active evacuation initiated by every change in the contractile state of the pelvic floor (as after micturition, defaecation or straining)

The proximal portion of the posterior urethral lumen is normally closed off from the urinary bladder on erection and ejaculation by contraction of the 'internal sphincter' When, however, this portion of the urethra and prostate is damaged, as after transvesical or transurethral prostatectomy, the imperfect closure of the uppermost part of the urethral lumen on ejaculation allows the passage of semen back into the urinary bladder The same seems to happen in severe diabetes mellitus The smooth muscled 'internal sphincter' is thus functionally assigned to the genital tract This assumption is corroborated by its *innervation the action of adrenergic drugs leads to contraction of this musculature* and to a decrease in detrusor tone, while cholinergic drugs have the reverse effect (LANGWORTHY et coll , and others)

The trigonal muscle also reacts in the same manner as the musculature of the genital tract to different forms of stimulation, but in a fashion opposite to that of the detrusor Accordingly, its function as the opener of the 'bladder neck' on micturition (WESSON (ref 39, 40, 41)) must be questioned (see also Fig 1, part I)

The view of the present authors on the initiation of micturition agrees with that of GOLTZ (ref 8) who, as early as 1874, maintained that urgency of micturition is experienced when urine reaches the posterior urethra, not because of its entry, and that urination is started by contraction of the bladder muscles *that propel the urine into the urethra*

Emptying of the posterior urethra of the same type as seen on vasography occurs when the external sphincter is contracted in connexion with voluntary contraction of the pelvic floor, as on interruption or completion of micturition The writers found that the column of contrast medium was always interrupted in a position corresponding to the diaphragmatic urethra, that is, by the external sphincter, and that this action was under the control of the will The filling of the prostatic urethra then persisted as long as the detrusor was contracted, but subsequently the medium was successively and actively propelled back into the bladder until the posterior urethra was finally wholly emptied If the sphincteric contraction was maintained for a sufficiently long period, the detrusor contraction also subsided and finally ceased entirely When, however, the contraction of the external sphincter was voluntarily released before the posterior urethra was emptied and before the detrusor contraction had subsided, micturition at once restarted The same observations have been made by several investigators in similar studies in women (ARDRAN et coll (ref 2), JEFFCOATE & ROBERTS (ref 14), ROBERTS (ref 33)) inter alios The same mechanism may be observed on coughing during micturition the accompanying contraction of the pelvic floor musculature, including the external sphincter, leads to a momentary interruption in the flow of urine, which sub

sequently continues as before If however, the contraction of the detrusor has subsided micturition cannot start until this muscle has once again contracted

The view expressed by MUELLNER (ref 28 29) that micturition is interrupted in the bladder neck by the action of the internal sphincter, was not verified in the present study

SUMMARY

Studies were performed on the emptying of the posterior urethra in normal and abnormal cases with a highly viscous water soluble contrast medium during active contraction of the pelvic floor It appeared that the external urethral sphincter is the chief regulator of micturition once the detrusor is contracted while the internal sphincter which closes the posterior urethra from the bladder in erection and ejaculation is really a muscle of the genital tract

ZUSAMMENFASSUNG

Die Entleerung der hinteren Harnrohre wurde mit viskösem wasserlöslichem Kontrastmittel in normalen und abnormalen Fallen studiert Es zeigte sich dass der externe Sphinkter die Hauptkontrolle der Blasenentleerung bildet sobald der Detrusor sich kontrahiert Der innere Sphinkter ist in Wirklichkeit ein reiner Genitalmuskel der die hintere Urethra bei der Erektion und Ejakulation von der Blase abschliesst

RÉSUMÉ

L évacuation de l urètre postérieur normal et pathologique a été étudiée avec un moyen de contraste hydrosoluble tres visqueux pendant la contraction active du plancher pelvien Il en résulte que le sphincter urétral externe est le principal régulateur de la miction quand le détrusor est contracté alors que le sphincter interne qui isole l urètre postérieur de la vessie pendant l érection et l éjaculation est en fait un muscle des voies génitales

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INTENTIONAL EMBOLISM IN SELECTIVE RENAL ARTERIOGRAPHY

An experimental study in dogs

by

N P G Edling and C O Ovenfors

Circumscribed infarctions in some of the kidneys occurred in an experimental study of the risks in selective renal catheterization and arteriography (Edling & Ovenfors 1964) It was suggested that the infarctions were caused by emboli due to clot formation during catheterization

The present paper is concerned with a further experimental study of selective renal arteriography associated with intentional renal embolism

Material and Method The examinations were performed in 6 healthy dogs, 2—3 years of age, and of weights ranging from 20 to 27 kg The dogs were kept under superficial anaesthesia by injection of thiomebumal sodium and pentobarbitone sodium into a hindleg The catheterizations were performed percutaneously via the femoral arteries and guided by image intensifier fluoroscopy Tephlon catheters were introduced into the right renal arteries in two dogs and

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Fig 1 a) Select e renal arteriogram in dog after intentional inj ct on of clotted blood Contrast defects in th a t rial b anches b) Lumbar ao tography after the selective arteriography illustrated in (a) Irregular ang onephrograph c effect with cort cal contrast defects f ll ng of enal vein

red Ödman catheters were passed into the left renal arteries in four dogs The catheters had end holes only The tephlon catheters were filled with Urografin 60 % (sodium methylglucamine diatrizoate) to render them visible Their exact position was checked by small test doses of Urografin 45 % an endeavour was made not to touch the origins of the opposite arteries

A dose of 0 1 ml Urografin 45 % per kg bodyweight was injected manually and a series of single films obtained for a preliminary study of the condition of the arteries and the kidneys to be examined About 2 ml of clotted blood from the dog in a small quantity of physiologic saline were then injected into the artery in 5 of the dogs and under 1 ml in the sixth dog A second selective arteriography was performed *after some* minutes Lumbar aortography was finally performed after a half to one hour and 1 ml Urografin 60 % per kg bodyweight was injected by means of an injection syringe into the aorta just above the origins of the renal arteries Roll films were used

Two of the dogs were kept alive for 2 weeks and four for 4 weeks after the experiments and all behaved in a normal way A second renal aortography was performed after 3 and 4 weeks respectively using red Ödman catheters in the two dogs in which tephlon catheters had been used

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Material and Method. The examinations were performed in 6 healthy dogs, 2—3 years of age, and of weights ranging from 20 to 27 kg. The dogs were kept under superficial anaesthesia by injection of *thiomebumal sodium* and *pentobarbitone sodium* into a hindleg. The catheterizations were performed percutaneously via the femoral arteries and guided by image intensifier fluoroscopy. Tephlon catheters were introduced into the right renal arteries in two dogs and

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tion of the left kidneys revealed wedge shaped nephron destruction of slight or moderate degree and fibrosis with the character of infarctions, in one of the kidneys moderate mineral salt deposits were also evident in the affected areas The opposite kidneys had no signs of infarction Three of the kidneys displayed slight pyelonephritic changes

Discussion

The initial intention was to use tephlon catheters as they do not stimulate clot formation Tephlon was used in fact in the first two dogs but were difficult to see during fluoroscopy in spite of their being filled with Urografin red Öd man catheters were used in the remaining experiments

The histologic examination of the kidneys revealed on an average slighter changes of the nephrons and more moderate deposition of mineral salts than in the series earlier reported by EDLING & OVENFORS The experiments in the lat ter series were carried out principally according to clinical rules and the cathe ters were in general introduced for a longer time It is surprising that the intentional embolism should cause lesions of a slighter degree than the spon taneous one It cannot therefore be excluded that regurgitation of the clotted blood from the renal artery injected into the aorta had reduced the blood supply to the branches of the renal artery This might be suggested by the bilateral infarctions of the kidneys in the dog in which only the right, higher renal artery was injected It may be noted that the end of the catheter had not migrated from the artery into the aorta It was observed how the clotted blood passed through the transparent tephlon catheters in fragments and not as a coherent mass It seems therefore reasonable to presume that spontaneously clotted blood at catheterization has a greater effect when embolizing than intentionally in jected clotted blood The absence of infarctions in the second dog in which a tephlon catheter was employed might thus be explained with due regard also to the small amount of clotted blood injected

The infarctions in three of the kidneys included calcifications in accord with the earlier findings (EDLING & OVENFORS) (Fig 2) This might suggest the pres ence of a latent hyperparathyroidism in the dogs the plasma contents of total calcium inorganic phosphorus and alkaline phosphatase of the six dogs were therefore estimated The amounts of calcium ranged from 10 1 to 10 6 mg/ 100 ml of inorganic phosphorus from 4 to 6 2 mg/100 ml and of alkaline phospha tase from 2 to 7 units/100 ml As these values are normal hyperparathyroidism in the dogs could be excluded The presence of the calcifications is therefore attributed to the necrosis of tissues caused by circulatory disturbance of the por tions of the kidneys supplied by plugged arteries

Any histologic changes attributable to the contrast medium or to the abnor mal angionephrographic effect at aortography occurring in two of the dogs were not found The latter phenomenon which was not associated with retention of

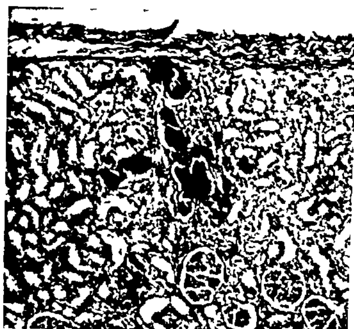


Fig 2 Section from canine kidney with infarction Fibrotic area with poor round cell infiltration and mineral salt deposits subcapsularly Van Gieson

The dogs were killed by desanguination and the kidneys removed immediately The kidneys were bisected, fixed in 10 % formalin, and prepared for microscopic examination

Results

The arterial filling and the angionephrographic effect appeared normal in the initial selective renal arteriographies of the dogs

The selective arteriographies, and the aortographies performed with tephlon catheters in two of the dogs just after the injection of the clotted blood, also revealed normal findings, as did the second renal aortographies The two dogs were killed four weeks after the main experiments The histologic examination of the kidneys revealed that both kidneys in one dog had small wedge shaped areas with nephron destruction, fibrosis and moderate mineral deposits, the changes having the character of infarctions No infarctions were evident in the second dog but only slight pyelonephritic changes which frequently are seen in dogs and are of no significance in the present study

Selective arteriograms, obtained after injection of clotted blood in two of the four dogs catheterized with Ödman catheters, revealed contrast defects in the arteries, probably caused by emboli (Fig 1a) in the aortograms, an irregular angionephrographic effect with cortical contrast defects were seen in the examined kidneys (Fig 1b) However, there was no retention of the contrast medium, and fading occurred at the same time as on the opposite side The angiographic findings were normal in the remaining two dogs Two of the dogs were killed after two weeks, and two after four weeks The histologic examina-

the contrast medium, did not therefore seem to be of any significance Nor did it occur in the remaining four dogs

The present experiments seem to have confirmed the suggestion of emboli as reasonable cause of infarctions of the kidneys in selective renal arteriography Mineral salt deposits, when present, indicate necrosis of the areas affected, however, these areas were small or very moderate in size in this series

SUMMARY

Intentional embolism in selective renal arteriography in a series of 6 dogs is reported Emboli appear to be the cause of the infarctions of kidneys found in the experimental studies

ZUSAMMENFASSUNG

Absichtliche Embolie wurde bei selektiver Nierenarteriographie an einer Serie von 6 Hunden hervorgerufen Embolie erscheint die Ursache der Infarktion zu sein die bei den Experimenten gefunden wurde

RÉSUMÉ

Les auteurs ont provoqué des embolies au cours de l *artériographie rénale sélective sur* une série de 6 chiens Les embolies sont la cause de l infarctus rénal constaté dans les études expérimentales

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Fig 2 a) Autopsy material The posterior pericallosal artery (→) arises at a backward bend of the medial choroid artery (⇢) just posterior to the foramen of Monro It also anastomoses with the anterior pericallosal artery which is filled in a retrograde manner b) Same specimen and same symbol as in (a) A small vessel (⇉) lies in the depth of the callosomarginal sulcus and is not seen on the medial surface of the specimen

Present investigation of normal anatomy of posterior pericallosal artery

Autopsy findings As no detailed description of the anatomy and radiologic appearances of the posterior pericallosal artery seems to exist a combined roentgen and dissection study of this artery in 17 half brain specimens was made The basilar artery was injected at necropsy with a gelatin and barium sulphate suspension after ligation of the posterior communicating arteries Specimens that had sufficient filling of the posterior pericallosal artery for dissection purposes were selected

The origin of the posterior pericallosal artery in the half brain specimens was as follows It emerged in 12 cases from the superior occipital branch of the posterior cerebral artery within the quadrigeminal cistern at about the posteroinferior margin of the splenium (The posterior cerebral artery divides into two branches a temporal and an occipital branch the latter giving rise to a superior and an inferior branch) It arose in two cases from a trunk in common with a supplementary branch of the medial choroid artery which had its origin more anteriorly from the superior occipital branch of the posterior cerebral artery beneath the splenium In one case it arose from the posterior cerebral artery within the ambient cistern in one case from the inferior occipital branch of the posterior cerebral artery and in one case from a backward continuation of the medial choroid artery within the roof of the third ventricle (Fig 2)

The artery in all the specimens passed around the splenium in a smooth curve with the convexity directed posteroinferiorly and then ran superoanteriorly within the cisterna corporis callosi

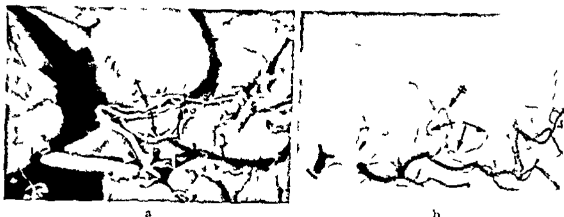


Fig 1 a) Autopsy specimen Posterior pericallosal artery emerging from the superior occipital branch of the posterior pericallosal artery (origin not seen) bends backwards beneath the corpus callosum and *swings out laterally (→) to supply the depth of the callosomarginal sulcus It sends a branch anteriorly* below the splenium (++) and also small twigs to the gyrus cinguli (+++) b) Same specimen The posterior pericallosal artery (→) is situated behind the medial (++) and lateral (++) choroid arteries

tricular dilatation The purpose of this study was to examine whether and how *the central branches of the posterior cerebral artery are affected by such dilatation*

Previous anatomical investigations The central branches of the posterior cerebral artery consist of the thalamo perforating arteries, the medial and lateral choroid arteries and the posterior pericallosal artery The thalamo perforating arteries originate from the proximal portion of the posterior cerebral artery, immediately to enter the substance of the thalamus from below, and are not directly affected by ventricular dilatation The anatomy of the medial and lateral choroid arteries was fully described in a previous study (GALLOWAY & GREITZ 1960) *so that a brief summary will now suffice*

The medial choroid artery, after coursing around the brain stem makes several loops roughly describing a figure of 3 lateral to the pineal body within the quadrigeminal cistern The terminal portion of the artery finally runs superomedially to course along the roof of the third ventricle adjacent to the internal cerebral vein (Fig 1b)

The lateral choroid arteries, after emerging from the posterior cerebral artery adjacent to the brain stem, describe a smooth curve with the convexity directed posteriorly as they run superomedially within the choroid fissure, they thus outline the anterior border of the trigone (Fig 1b)

In most anatomical textbooks *no mention is made of the posterior pericallosal* artery although it is frequently seen in sketches of autopsy specimens In spite of the fact that this artery often forms a connection with a pericallosal artery it is not specifically mentioned in VAN DER ECKEN s monograph on leptomeningeal anastomoses KRAYENBUHL & YASARGIL refer to the posterior pericallosal artery but give *no description of its origin, course or variations*

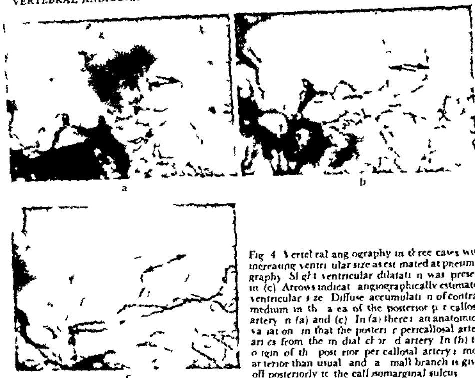


Fig 4 Vertebral angiography in three cases with increasing ventricular size as estimated at pneumography Slight ventricular dilatation was present in (c) Arrows indicate angiographically estimated ventricular size Diffuse accumulation of contrast medium in the area of the posterior pericallosal artery in (a) and (c) In (a) there is an anatomical variation in that the posterior pericallosal artery arises from the medial choroid artery In (b) the origin of the posterior pericallosal artery is more anterior than usual and a small branch is given off posteriorly to the callosomarginal sulcus

tion (index of hydrocephalus less than 0 33) as well as in 35 additional cases with negative vertebral angiographies most of which were examined for subarachnoid bleeding

The posterior pericallosal artery at vertebral angiography was seen to extend superiorly from the posterior cerebral artery about one centimeter behind the curve of the lateral choroid arteries and could usually be identified by the backward bend it made at the anteroinferior margin of the splenium (Fig 3a) In cases in which it was possible to trace its origin more posteriorly to the inferior occipital branch of the posterior cerebral artery this bend could not be identified so that confusion with the more laterally located arteries within the cistern of the corpus callosum sometimes arose This mistake is however of no practical importance as these vessels also define the outer surface of the splenium a surface that is also outlined by a diffuse accumulation of contrast medium within the brain fissure adjacent to the more poorly vascularized corpus callosum (Fig 4 a and c and Fig 5 a and b) A similar phenomenon may be seen on carotid angiography (GREITZ 1956)

The pericallosal artery sometimes arose more anteriorly and obviously within the ambient cistern (Fig 4b) and occasionally from the medial choroid artery (Fig 4a) The origin and course of the artery could be different on the two

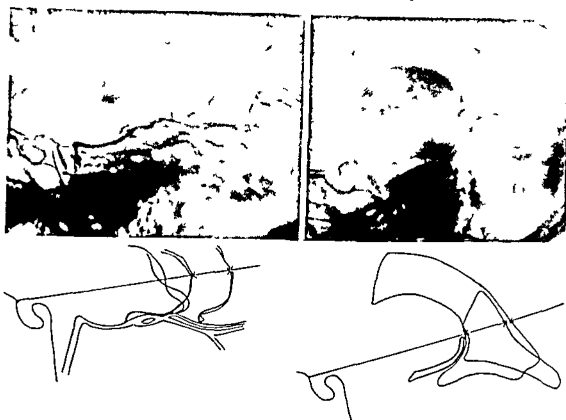


Fig 3 Vertebral angiography and pneumography in a normal case Typical origin and course of posterior pericallosal arteries sketches show the methods of measurement used in the study

In the 12 specimens in which the origin was from the superior occipital branch of the posterior cerebral artery, the posterior pericallosal artery had a characteristic course in that it ran anteromedially to the anterior margin of the splenium and then made a backward bend upon itself before coursing around the splenium (Fig 1)

It often passed laterally to the depth of the sulcus corporis callosi, at the posterior aspect of the corporis callosum, and also gave small twigs anteriorly below the splenium and posterosuperiorly to the cingulate gyrus

In several of the specimens, a small, more laterally situated artery, also arising from the superior occipital branch of the posterior cerebral artery, ran superiorly to vascularize the depth of the sulcus corporis callosi This vessel in lateral views had more or less the same appearance as the posterior pericallosal artery, however, it usually had its origin somewhat more posteriorly than the latter and did not present the above mentioned backward bend beneath the splenium, facts that helped to differentiate this artery from the posterior pericallosal artery

Angiographic findings Observations were made in 25 cases that had both vertebral angiography and pneumography and that showed no ventricular dilata

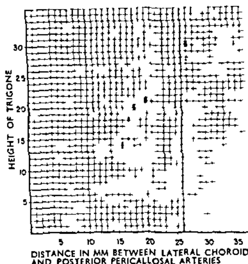


Fig 6 Correlat on between the height of the t gone measured as in fig 3 and the ang o graphically est mated ventricular size Dots repres nt normal cases cros es cases with ven tricular d latat on

sides branches from one vessel sometimes ran mainly anteriorly below the splenium while branches from the other artery passed backwards and superiorly around the splenium (Fig 5d) The superior extension at the artery within the cisterna corporis callosi varied in length usually by one or two centimeters In some cases no extension superiorly beyond the curvature of the splenium was observable but occasionally branches from the posterior pericallosal artery extended beyond the cingulate gyrus to supply the callosomarginal sulcus (Fig 4b)

The inferior anterior body of the trigone is formed by the thalamus, which is in close connection with the choroid fissure in which lie the lateral choroid arteries The distance between the posterior pericallosal artery curving around the corpus callosum and the lateral choroid arteries situated behind the thalamus within the choroid fissure should consequently give an indication of the size of the posterior part of the lateral ventricle it may also possibly serve as an index of the degree of hydrocephalus in a similar way as the frontal diameter of the anterior horn

Angiographic changes in lateral ventricular dilatation

A material consisting of 10 cases with central atrophy and 23 cases with obstructive hydrocephalus was studied in order to examine the anatomical changes of the central branches of the posterior cerebral artery that occur in ventricular dilatation Only cases that had been examined with pneumography were chosen

Dilatation of the lateral ventricles occurs either by disturbance of the liquor drainage or by a reduction in volume of the cerebral tissue The pneumographic changes seen in ventricular dilatation are well known The third ventricle may

a

b

c

d



e

Fig. 3. Vertebral angiography in 4 cases of obstructive ventricular dilatation. Posterior pericallosal arteries (→), lateral choroid arteries (↔) and medial choroid arteries (⇔). a) Hydrocephalus of degree 0.37, angiographic measurement 27 mm. Lateral choroid arteries unchanged, medial choroid arteries slightly depressed, no stretching of posterior cerebral arteries. b) Pinealoma with hydrocephalus of 0.49 degree, angiographic measuremnt 30 mm. No obvious stretching of posterior cerebral arteries, lateral choroid arteries relatively unchanged, medial choroid arteries displaced backwards and upwards by tumor. c) Hydrocephalus not measureable due to posterior pericallosal arteries being displaced inferiorly. Choroid arteries depressed and streched. d) and e) Aqueduct stenosis with hydrocephalus not measurable due to the choroid arteries being depressed and deformed. The medial choroid arteries are streched; there is a vascular anomaly in that one posterior pericallosal artery is running anteriorly below the splenium and the one arising posteriorly is curving backwards and upwards; together these arteries indicate a wider bow of the outer surface of the splenium than the normal. The hydrocephalus is obvious also from changes in the central veins (→) (e). In this and the previous case the diagnosis of hydrocephalus may be made from the stretching of posterior cerebral arteries but above all from changes in *their central branches*.

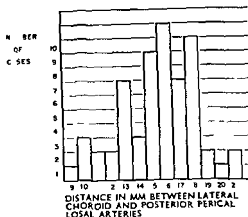


Fig 7 Distribution of angiographically determined ventricular size in 60 normal cases

Measuring technique The writers found it suitable to measure the distance between the lateral choroid arteries within the choroid fissure and the posterior pericallosal arteries within the cisterna corporis callosi as an estimation of the height of the body of the lateral ventricle situated between the thalamus and the corpus callosum In practice the distance between the most posterior point along the curvature of the lateral choroid arteries and the posterior pericallosal arteries is measured on a line connecting the tuberculum sellae through the posterior point and cutting the posterior pericallosal arteries (Fig 3) If the line does not cut the posterior pericallosal arteries the course of the arteries is extended in the general direction of their curvature superiorly until they reach this line However if the posterior pericallosal arteries are so short that no estimation of the direction of their curvature superiorly within the cisterna corporis callosi is obtainable then the case cannot be measured (The presence or absence of lateral ventricular dilatation may however be detected from the appearance of the curve of the posterior pericallosal arteries around the splenium from changes in the position of the medial and lateral choroid arteries from displacement of the central veins and finally from the straightening of the posterior cerebral arteries) The lateral choroid arteries may be so flattened and depressed in cases that exhibit marked ventricular dilation that the backward convex curvature is absent or the posterior pericallosal artery may be depressed beyond the extension of the prementioned line The above described measurement consequently cannot be applied in such cases but an estimation of lateral ventricular size is obtainable from noting the distance between the depressed choroid arteries and the backward displaced posterior pericallosal artery Hydrocephalus in these cases is usually already apparent from the straightening of the posterior cerebral arteries (Fig 5 c and d)

In order to determine how the distance between the lateral choroid and the posterior pericallosal arteries reflects lateral ventricular size the distance in the

be depressed in hydrocephalus, which never occurs in atrophy It seems likely that this difference be reflected in the shape of the medial choroid artery coursing along the roof of the third ventricle Irrespective of the cause of ventricular dilatation the main body of the callosum becomes elevated The inferior anterior border of the trigone may be slightly displaced anteroinferiorly

On *vertebral angiography*, performed in cases with marked ventricular dilatation, it was found that the above mentioned distance between the posterior pericallosal artery and the lateral choroid arteries, as measured in the lateral projection, was apparently increased Furthermore, the posterior pericallosal artery ran in a greater curve than normally (Fig 5, a and b) In greater degrees of hydrocephalus the splenium was shifted posteroinferiorly into the quadrigeminal cistern, and consequently the portion of the posterior pericallosal artery that curves around the splenium was displaced in the same direction and straightened (Fig 5, c and d) In addition the angle formed by this vessel at the anterior inferior margin of the splenium became more acute than normal

The terminal portion of the medial choroid artery, in cases that exhibited a high degree of obstructive hydrocephalus with depression of the third ventricle, was displaced inferiorly and straightened (Fig 5, a, c, and d) As these changes were absent in non obstructive ventricular dilatation they constitute a possibility of differential diagnosis Depression of the dilated third ventricle was sometimes absent even in marked hydrocephalus, in such cases the medial choroid artery was not depressed but instead even slightly elevated The lateral choroid arteries were in most cases relatively unchanged although they might be displaced somewhat anteroinferiorly, in marked hydrocephalus they were depressed (Fig 5d) The choroid veins were seen to be changed in the same manner as the corresponding arteries (Fig 5c)

Measurements

Material The distance between the lateral choroid and the posterior pericallosal arteries was measured in the lateral projection in an attempt to evaluate the possibilities in estimating ventricular size in vertebral angiography The above mentioned material was used for this purpose and consisted of cases with and without ventricular dilatation in which both pneumography and percutaneous vertebral angiography had been performed

About a quarter of the cases had to be excluded because sufficient filling of the lateral choroid arteries had not been achieved (CRONQVIST 1960), another 10 % were omitted due to unsatisfactory filling of the posterior pericallosal artery Cases with the highest degree of hydrocephalus also had to be excluded from the material, for a reason that will be explained later A few cases with considerable unilateral dilatation were also not included

Thirty eight cases were left for measurement, thirteen of these 38 cases presented evidence of ventricular dilatation, in 6 cases due to cerebral atrophy and in 7 cases caused by posterior fossa tumors with secondary hydrocephalus

that had both pneumography and vertebral angiography, with no observable ventricular dilatation and an index less than 0 33) It is seen that 3 out of the 60 cases exhibited an arterial measurement greater than 19 mm However in two of these cases the lateral ventricles were unusually wide posteriorly without being definitely dilated None of the 60 cases had a measurement greater than 21 mm (Fig 7)

The width of the lateral ventricle, measured as the shortest distance from the inner upper angle of the lateral ventricle to the caudate nucleus in the frontal pneumogram (distance of Troland Baxter & Schatzki), according to KNUDSEN (1958) more adequately reflects ventricular size than does the width of the anterior horn As seen in Fig 8 a linear correlation also exists between the former measurement and the distance between the lateral choroid arteries and the posterior pericallosal artery It may thus be said that the arterial measurement in effect correlates with the linear measurements used to estimate the size of the body of the lateral ventricle in the sagittal and the coronal plane and may therefore be used as an expression of a degree of hydrocephalus The degree of hydrocephalus in the 13 measurable cases of the present material with ventricular dilatation ranged between 0 35 to 0 45 Straightening of the posterior cerebral arteries was present in only one of these cases

The correlation between the degree of hydrocephalus and the distance between the lateral choroid and the posterior pericallosal arteries is shown in Fig 9 It is evident that in cases with ventricular dilatation a correlation exists between the arterial measurement and the size of the anterior part of the lateral ventricles

As to the normal material no such correlation is apparent and this must be due to the fact that in a normal material no greater correlation exists between the width of the anterior horn and the height of the trigonum It is apparent that 9 out of the 13 cases that had a degree of hydrocephalus greater than 0 32 (upper limit of normal) had measurements between the lateral choroid arteries and the posterior pericallosal greater than 19 mm, while the other four cases which had an angiographic measurement less than 19 mm had only a slight degree of hydrocephalus It may also be noted that 2 out of the 25 cases that had an index less than 0 33 had a measurement between the arteries greater than 19 mm however these were the cases in which the posterior portions of the lateral ventricles were unusually wide

If it be assumed that 21 mm is the upper limit of normal for the arterial measurement then from Fig 7 it is apparent that 5 out of the 13 cases that exhibited degrees of hydrocephalus greater than 0 32 were detected from measurements these 5 cases range between the degree of hydrocephalus of 0 39 and 0 49 and in none of them (all of which had generalized lateral ventricular dilatation) was there straightening of the posterior cerebral arteries The ventricular dilatation was however already probable from the wide curve formed by the posterior pericallosal artery

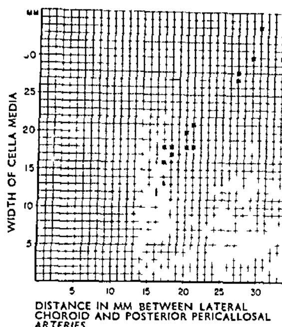


Fig 8 Correlation between width of lateral ventricle measured as shortest distance between inner upper angle of lateral ventricle and caudate nucleus and angiographically estimated ventricular size Same symbols as in fig 6

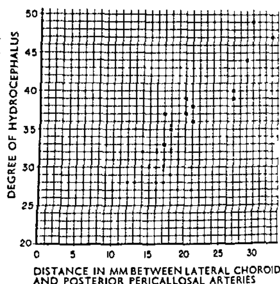


Fig 9 Correlation between degree of hydrocephalus (quotient of width of lateral ventricle and width of corresponding half of cranium as measured in frontal pneumogram) and angiographically estimated ventricular size Same symbols as in fig 6

sagittal plane between the floor and the superior aspect of the roof of the body of the lateral ventricle in the lateral pneumogram was measured in a manner similar to that used in the arterial measurement A line was drawn from the tuberculum sellae through the most posterior point along the curvature of the anterior limit of the trigone superoposteriorly until it cut the roof of the lateral ventricles, and the distance from the floor to the roof was measured along this line (Fig 3) If small differences existed between the size of the lateral ventricles, the mean value was taken (Fig 3d), however, the few cases in which considerable unilateral ventricular dilatation was present were not included in the material

Results

A linear correlation (Fig 6) was found to exist between the distance from the floor to the roof of the trigone and the distance between the lateral choroid arteries and the posterior pericallosal arteries In order further to investigate the limits of normal for the arterial measurement, the distance between the lateral choroid arteries and the posterior pericallosal artery was recorded in 35 additional 'normal' cases (35 cases with negative vertebral angiographies, most of which were examined for subarachnoid bleeding, in addition to the 25 cases

ZUSAMMENFASSUNG

Die Anatomie und die Röntgenerscheinungen der zentralen Äste der Arteria cerebri posterior und deren Beeinflussung durch Erweiterung des Ventrikelsystems wird anhand von Sektionsergebnissen und angiographischen Untersuchungen nach intra vertebraler Injektion am Lebenden besprochen. Besondere Aufmerksamkeit verdient die Arteria pericallosa posterior. Es wird aufgezeigt, wie die Höhe des hinteren Teiles des Seitenventrikels zwischen Thalamus und Balken durch vertebrale Angiographie abgeschätzt werden kann.

RÉSUMÉ

Les auteurs, se basant sur des autopsies et des angiographies vertébrales sur le vivant, décrivent l'anatomie et les images radiologiques des branches centrales de l'artère cérébrale postérieure et l'influence sur ces branches de la dilatation ventriculaire. Ils ont particulièrement étudié l'artère péricalleuse postérieure. Ils donnent un moyen pour mesurer par angiographie vertébrale la hauteur de la partie postérieure du ventricule latéral entre le thalamus et le corps calleux.

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Conclusions

The central branches of the posterior cerebral artery undergo characteristic changes in ventricular dilatation The changes evident in hydrocephalus may to a certain extent be differentiated from those in central atrophy The veins within the tela choroidea are also affected by ventricular dilatation

The central branches of the posterior cerebral artery are sufficiently filled for estimation of the size of the lateral ventricles in about 60 per cent of cases subjected to percutaneous vertebral angiography The height of the posterior part of the lateral ventricle can be measured as the distance between the lateral choroid and the posterior pericallosal arteries This measurement is correlated with the height of the posterior part of the lateral ventricle and is also correlated with the width of the body of the lateral ventricle measured at pneumography as the distance from the upper insertion of the septum perpendicular to the caudate nucleus Moreover, in cases with ventricular dilatation a correlation exists between the same arterial measurement and the relative width of the anterior horn, the latter measurement commonly being used to indicate 'the degree of hydrocephalus Judging from this small material, a measurement between the lateral choroid and the posterior pericallosal arteries of more than 21 mm indicates lateral ventricular dilatation It should be born in mind that an increase in the angiographic measurement may be due to localized posterior ventricular dilatation

The distance between the lateral choroid and posterior pericallosal arteries cannot be measured in a few cases of marked hydrocephalus The diagnosis of hydrocephalus in these cases is however easily made from changes in the appearance of the posterior cerebral artery and its central branches The diagnosis of ventricular dilation may be made before any straightening of the posterior cerebral artery arises by observing the distance between the lateral choroid arteries and the posterior pericallosal arteries

Acknowledgement

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SUMMARY

The anatomy and roentgenologic appearances of the central branches of the posterior cerebral artery and the influence of ventricular dilatation are discussed on the basis of autopsy studies and observations at vertebral angiography in living subjects Special attention is directed to the posterior pericallosal artery A means of estimating the height of the posterior part of the lateral ventricle between the thalamus and corpus callosum by vertebral angiography is described

intravasal erythrocyte aggregation has any part in producing such side effects different contrast media were studied in a clinical material to determine their propensity to produce or increase intravascular clumping Supplementary experiments were carried out in cats mainly in order to ascertain the degree of the side effects caused by these media in 'clinical doses In view of the correlation considered to exist between intravascular erythrocyte aggregation and the suspension stability of the red cells the sedimentation rate of these cells was investigated after both their in vivo and in vitro exposure to different contrast media

Material and Methods

The intravascular erythrocyte aggregation was studied in conjunctival vessels with the aid of vital microscopy (magnification × 60) in connection with 56 clinical examinations with various contrast media The microscopic observations were started about one minute before the respective injections and were continued for about 10 minutes after the termination of the injection

The grading of the findings was necessarily subjective but in order to eliminate as far as possible inconsistent interpretations the degree of aggregation was classified as one of four well defined types

Type 1 — No visible granular flow

Type 2 — Distinct granular flow but no reduction in flow rate

Type 3 — Granular flow with reduction in flow rate here and there

Type 4 — Granular flow with reduced circulation and in places stagnation of red blood cells

Only a change over from one of these types to another was recorded as an unequivocal change Twenty ml adipiodon (Biligrafin forte 50 %) were injected in 25 cases and 20 ml diatrizoate in 31 cases Among the latter 20 ml Urografin 60 % was used in 25 instances and 20 ml Hypaque 50 % in 6 instances All the microscopic work was performed by one and the same member of the team (Lofstrom) and this examiner had no knowledge of which contrast medium had been used in the different cases In most cases (48) 20 ml physiologic saline solution was also injected the examiner was not informed of the order in which the contrast medium and saline injections had been given The injections were usually carried out at a rapid rate over a time shorter than 30 seconds In 5 cases because of high age or cardiac disease Biligrafin forte was injected during 1 to 2 minutes The patients were closely watched for circulatory complications in connection with all the Biligrafin injections no alarming side reactions were observed in this material although nausea or vomiting occurred in 13 instances

The animal experiments were performed in 23 cats weighing from 2 0 to 4 3 kilograms The ventral part of the neck was dissected with insertion of a Y shaped tracheal cannula and exposure of both common carotids following anaesthetization with pentobarbital sodium (Nembutal Abbott) 35 mg/kg

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INTRAVASCULAR ERYTHROCYTE AGGREGATION AFTER INTRAVENOUS INJECTION OF CONTRAST MEDIA

by

PERCY LINDGREN, BERTIL LOFSTROM and GEORG FREDRIK SALTZMAN

Our arsenal of contrast media for parenteral administration is still heterogeneous as regards degree and frequency of side effects. Since the sodium acetrizoate preparations were supplanted by diatrizoate compounds, examinations of the vascular system and urinary tract have only occasionally caused patients any discomfort that could be attributed to the contrast medium. Only very large doses of diatrizoate compounds in high concentration, such as those used for intravenous aortography by some investigators in America, seem to involve risks in themselves. Adipiodon (Biligrafin, Cholografin) however, which has been widely applied during the past ten years for non-operative contrast studies of the bile ducts, has often produced noteworthy and in exceptional cases highly dangerous side reactions even when used in small doses.

American investigators in recent years have suggested that there may be a connection between intravascular aggregation, i.e. clumping of the red blood cells, and complications from contrast media. In order to investigate whether

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intravasal erythrocyte aggregation has any part in producing such side effects different contrast media were studied in a clinical material to determine their propensity to produce or increase intravascular clumping Supplementary experiments were carried out in cats mainly in order to ascertain the degree of the side effects caused by these media in 'clinical doses In view of the correlation considered to exist between intravascular erythrocyte aggregation and the suspension stability of the red cells the sedimentation rate of these cells was investigated after both their in vivo and in vitro exposure to different contrast media

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The animal experiments were performed in 23 cats weighing from 2 0 to 4 3 kilograms The ventral part of the neck was dissected with insertion of a Y shaped tracheal cannula and exposure of both common carotids following anaesthetization with pentobarbital sodium (Nembutal Abbott) 35 mg/kg

intraperitoneally Succinylcholine (Celocurin, Vitrum) was given in some cases to prevent muscular movements and vomiting when large doses of contrast media were given, in those cases artificial respiration was maintained throughout the experiment

The contrast media were injected intravenously (unless otherwise stated) via a thin polythene catheter inserted in a cutaneous vein of a foreleg The parameters were recorded by a Grass Model 5 Polygraph as follows The systemic blood pressure was recorded in all experiments from the cannulated left carotid artery or from the femoral artery by means of a Statham transducer

The right ventricular pressure was recorded in 8 cases A polythene catheter with its tip slightly curved was placed in position via the right jugular vein and connected with another Statham transducer, in those cases in which heparin was not given, 1 to 2 ml saline were injected at regular intervals to prevent clotting at the tip The pressure in the pulmonary artery was recorded in 3 cases, the thorax was opened under artificial respiration and a cannula inserted in a retrograde direction into a lobular branch of the right pulmonary artery

The peripheral blood flow was measured by a direct method of photo electric drop recording (LINDGREN, and GOLDSCHMIDT & LINDGREN) The apparatus could in principle be inserted into any artery or vein These animals were given heparin, 25 mg/kg

The blood flow in the conjunctival vessels in a few experiments was observed under the microscope in order to study whether aggregation of the red blood cells took place following the injection of contrast medium

The sedimentation rate of human blood was investigated in Westergren tubes, all values being read off after 1 hour The rate after in vivo exposure to adipiodon was studied in 12 cases by comparing the values obtained before and after the injection of 20 ml Biligrafin forte (50 %) The influence of diatrizoate on the sedimentation rate was studied in 19 cases by measurements carried out before and after injection of 20 ml Urografin 60 % The sedimentation rate after in vitro exposure to Biligrafin forte (19 cases) and to Urografin 60 % (19 cases) was determined after 2 ml of blood had been mixed with 0 04 ml of the respective contrast medium

Results

Intravascular aggregation in human subjects The results of the vital microscopic studies on the conjunctiva are shown below

	Cases	Increased aggregation
Biligrafin	25	15
Urografin	25	4
Hypaque	6	0
Saline	48	2

It could be expected that the side effects which developed in some of the cases particularly after the injection of Biligrafin forte might have misled the examiner into unconsciously overrecording increased intravasal aggregation This seems highly improbable, however as the increase in the clumping was in all except one case manifest before other secondary reactions appeared It is evident that Biligrafin caused increased aggregation in more than half the cases In 5 of the 15 cases showing an increased aggregation the phenomenon was so marked that it implied a change over from Type 1 to Type 3 or from Type 2 to Type 4 in the other 10 cases it was of a degree warranting removal to the next aggregation type Microscopic examination of the conjunctiva disclosed that this increased aggregation had exactly the same appearance as that seen after injury or in infections It arose immediately after the termination of a rapid in jection The disturbance in the blood flow showed slight variation in duration The blood stream in most cases had within 10 minutes resumed the appearance that was observed before the injection of the Biligrafin

Increased red cell aggregation was commoner among cases with nausea after the Biligrafin injection (9 out of 13) than among those without any side reac tions (6 out of 12) The material is however too small to allow definite conclu sions to be drawn regarding this feature

Contrast media of the sodium diatrizoate type seldom caused any noticeable increase in the red cell aggregation In the 4 cases in which such a phenomenon was observed the disturbance implied a change over to the next aggregation type Nausea arose after the contrast injection in 2 of the 4 cases with increased aggregation whereas it was noted in only one of the cases showing no change in the aggregation None of the 6 patients given Hypaque had side reactions

Slightly increased aggregation was noted in 2 of the 48 cases given a saline injection It should be mentioned however that one of these cases already had a conjunctival inflammatory reaction with primary fairly severe slightly varying red cell aggregation while in the other case the suspected aggregation increase lasted for only a few seconds and hence for a shorter time than the correspond ing change in all cases given a contrast injection in both cases the saline solu tion had been injected before the contrast medium

Circulation studies in cats

Adipiodon The results of the cat experiments confirmed our previous obser vations that clinical doses of adipiodon (Biligrafin forte 0 33 ml/kg) given intravenously produced a fall in the systemic blood pressure (SALTZMAN & SUND STROM LINDGREN & SALTZMAN) This dose was used in most of the experiments but in some of them in order to obtain more clear cut differences between the responses to the various contrast media higher doses (0 5 or 1 0 ml/kg) were used

Parallel with the fall in the systemic blood pressure an increase in the right ventricular pressure could be demonstrated in most experiments (Fig 1)

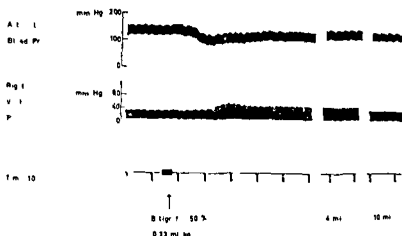


Fig 1 Decreased arterial blood pressure and increased right ventricular pressure following Biligrafin injection

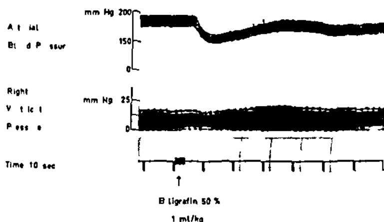


Fig 2 Decreased arterial blood pressure and more or less unchanged right ventricular pressure following Biligrafin injection after pretreatment with low molecular weight dextran

the systolic pressure rising to 10 to 60 per cent above the original level of 25 to 35 mm Hg The peak of the rise occurred 10 to 20 seconds after the injection and gradually declined during the course of 2 to 10 minutes

A few cats were pretreated with low molecular weight dextran (Rheomacrodex, 15 ml/kg), which is known to prevent red cell clumping, in order to study the role of erythrocyte aggregation as a possible cause of the pulmonary hypertension and decrease in systemic blood pressure Owing to the fact that repeated doses of Biligrafin, given at short intervals always gave smaller responses than the first one, in other words that a kind of tachyphylaxis seemed to develop (LINDGREN & SALTZMAN), the responses to subsequent doses could not be compared quantitatively Thus the effects of Biligrafin before and after Rheomacrodex could not be compared in one and the same experiment The right ven

tricular hypertension evoked by Biligrafin was much weaker in cats pretreated with Rheomacrodex however as seen in Fig 2 a fall in systemic blood pressure occurred even in the absence of pulmonary circulatory response

No significant response pattern was observed as far as the peripheral blood flow (in skeletal muscles skin and intestines) was concerned When larger doses of Biligrafin were given and an abrupt fall in the systemic blood pressure occurred a parallel reduction in the peripheral blood flow was seen as has also been described elsewhere (LINDGREN & SALTZMAN) The peripheral blood flow changes were unaffected by pretreatment with Rheomacrodex as in the case of the systemic blood pressure fall

In four experiments in which the blood stream in conjunctival vessels was observed microscopically it was possible to establish that intravenously administered Biligrafin also in cats caused aggregation of the red blood cells lasting for a few minutes The examiner was unaware of the type of substance injected as in the observations in human subjects No attempt was made to carry out a long series as the technical problems in making these observations with all the other recording devices attached to the animal were considerable

Other contrast media For comparative purposes the following substances (given intravenously in doses of 0 5 or 1 0 ml/kg) were also studied Hypaque 50 % and Urografin 60 % (diatrizoate), Urokon 50 % (acetrizoate) and NaCl solution 0 9 % 4 5 % and 9 %

Only Urokon produced an increase in the right ventricular pressure of the same magnitude as the responses to Biligrafin (cf Fig 3) This compound also produced a noteworthy fall in the systemic blood pressure A transient increase in erythrocyte aggregation could be observed in the conjunctival vessels following injection of Urokon

The responses to Hypaque Urografin and hypertonic NaCl were weak and insignificant and consisted only in minor fluctuations of the systemic blood pressure No appreciable increase in right ventricular pressure was observed with these compounds

Sedimentation rate in human subjects

In vivo measurements Definitely lower numerical values were obtained after the contrast injection in 7 of the 12 cases in which the sedimentation rate was measured before and after injection of 20 ml Biligrafin forte The average sedimentation rate in these 12 cases was 32 mm before and 24 mm after administration of the contrast medium

The sedimentation rate showed a moderate reduction in 5 of the 19 cases given 20 ml Urografin 60 % the average rates before and after the contrast injection were 14 mm and 12 5 mm respectively, in these 19 cases

In vitro measurements Among the 17 cases in which blood was mixed in vitro with Biligrafin forte from freshly opened ampoules a reduction in the sedimenta

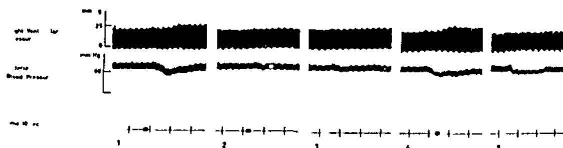


Fig. 3. Arterial blood pressure and right ventricular pressure following injection of different contrast media and saline

1	*Biligrafin 50 %*	*0.5 ml/kg*
2	Hypaque 50	1.0 ml/kg
3	Urografin 60 %	1.0 ml/kg
4	Urokon 50 %	0.5 ml/kg
5	NaCl 9 %	0.5 ml/kg

tion rate was observed in 15 instances, in the majority of them it was marked. The average sedimentation rates in these 17 cases before and after exposure to the contrast medium were 30 mm and 4 mm, respectively.

It should be mentioned that Biligrafin forte left standing for 2 weeks in daylight in an opened ampoule was used in 3 cases, in all of these an increased sedimentation rate was noted.

A slight reduction in the sedimentation rate was recorded in 10 of the 19 cases in which human blood was mixed in vitro with Urografin 60 %. The average settling rate in these cases was 28 mm before and 24 mm after exposure to the contrast medium.

Discussion

Research on the toxicity of parenterally administered contrast media has during recent years mainly been concentrated on the effects on the circulation and on various types of blood changes. LINDGREN et coll. in several experimental studies demonstrated that sodium acetrizoate and adipiodon, when injected intra-arterially, cause an increase in the peripheral arterial blood flow, while SALTZMAN et coll., both in experimental and in clinical investigations, observed a considerable fall in the arterial blood pressure after intravenous injection of these two contrast media. Signs of a slight increase in the peripheral arterial blood flow are noticeable after intra-arterial injection of sodium diatrizoate, but the heightened flow is insignificant compared with that seen after the administration of the previously mentioned preparations. Significant circulatory changes after the intravenous injection of sodium diatrizoate have

been observed only when the doses have been very large (READ BERNSTEIN & EVANS)

The significance of the effect produced by certain contrast media on different blood components has been discussed from the standpoint of the side reactions to the preparation CHAPLIN & CARLSSON observed certain changes particularly in the red blood cells in response to sodium acetrizoate in large doses in vitro Crenation of the red cells as well as haemolysis have also been observed LASSER et coll pointed out that acetrizoate and adipiodon cause crenation of the red cells while sodium diatrizoate compounds mainly appear to give rise to rouleau formation The lastmentioned authors considered that the power of sodium acetrizoate and adipiodon to bind albumin is of importance they drew a parallel between this property and the relatively high toxicity of these contrast media The less toxic diatrizoate preparations would appear to have a much lower propensity for binding protein

The observation that certain compounds may cause an increase in the intra vascular aggregation of the red blood cells forms an interesting contribution to the discussion of the side effects produced by these contrast media READ and BERNSTEIN & EVANS in experimental studies observed increased red cell ag gregation after the intravenous injection of large doses of a sodium diatrizoate compound (Hypaque) At the same time they observed an increase in pres sure in the pulmonary artery, in their opinion due to erythrocyte aggregation since low molecular weight dextran which is known to be capable of preventing or decreasing red cell clumping (THORSEN & HINT, GELIN & ZEDERFELDT and others) eliminates or reduces this pressure increase These authors considered that the pressure fall which they had noted in the peripheral circulation was sec ondary to the pressure increase in the pulmonary artery SOBIN et coll in clini cal material observed increased aggregation of the red cells after injection of a 30 ml sodium diatrizoate (Hypaque 50 %) and sodium diprotrizoate (Miokon 50 %)

The results described in the present paper give only partial support to the hypothesis that erythrocyte aggregation caused by intravenous contrast media may explain some of the circulatory side effects that obviously accompany these compounds We have demonstrated that those contrast media (Biligrafin and Urokon) that give the most marked circulatory reactions also produce erythro cyte aggregation and an increase in the right ventricular pressure It is noteworthy that the increased aggregation agrees remarkably well in time with the blood pressure fall occurring consistently after all Biligrafin injections (SALTZMAN & SUNDSTROM) Contrast media known to give less marked side reactions produce a lesser degree of aggregation The diatrizoate salts for instance when given in the doses used for urography seldom cause such a change The lastmentioned observation clashes to some extent with the assertion of SOBIN et coll that sodium diatrizoate (Hypaque 50 %) and sodium diprotrizoate (Miokon 50 %) in doses of 30 ml usually cause aggregation of the red cells their doses were lightly

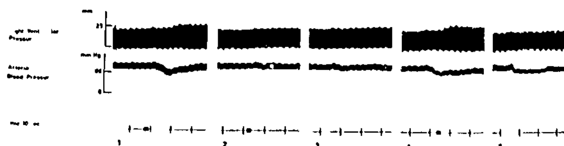


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5	NaCl 0.9 %	0.5 ml/kg

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and in vivo A similar tendency was also observed with diatrizoate This is surprising seeing that both theoretically and according to many clinical observations increased aggregation of the red cells causes an increase in the sedimentation rate BERNSTEIN et coll, in investigations on certain physico chemical properties of blood after exposure to different contrast media, recently attempted to ascertain the causes underlying these apparently opposing effects The findings again bring into the foreground the long felt need for more objective methods for the study of intravascular aggregation It is not unlikely that underlying the intravascular aggregation observable at vital microscopy of the conjunctival vessels there may be clumping phenomena with widely differing mechanisms

SUMMARY

An investigation of the intravascular erythrocyte aggregation by vital microscopy after the injection of adipiodon and diatrizoate in 56 human subjects and the effect of these contrast media with and without pretreatment with low molecular dextran in experimental circulation studies in cats is reported The influence of the media which was observed in vitro and in vivo is discussed

ZUSAMMENFASSUNG

Die intravaskulare Erythrocytaggregation wurde in 56 Patienten nach Injektion von Adipiodon und Diatrizoat vital mikroskopisch studiert und es wird uber den Effekt dieser Kontrastmittel mit und ohne Vorbehandlung mit Dextran von kleiner Molekulargrosse in Zirkulationstudien an der Katze berichtet Die Resultate in vivo und in vitro werden diskutiert

RÉSUMÉ

Les auteurs présentent leurs recherches par examen microscopique vital sur l agrégation intravasculaire des globules rouges apres injection d adipiodone et de diatrizoate à 56 sujets humains et sur l effet de ces moyens de contraste précédés ou non d un traitement par un dextrane de faible poids moléculaire au cours d une étude expérimentale de la circulation sur des chats Les auteurs étudient l effet de ces moyens de contraste observé in vitro et in vivo

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larger, however, and the sludge was moreover recorded photographically, a method probably permitting the demonstration of smaller changes than those we could record.

It would appear unlikely that the increase in the right ventricular pressure observed by the present authors could have been due to the hypertonicity of the contrast media as such. In the first place, clear differences in response were noted between the different contrast media, which did not differ appreciably as regards the osmotic pressure of the solutions, and in the second place, this effect was not observed after injection of a hypertonic saline solution. It *should be mentioned that any effect on the pressure in the right ventricle after intravenous injection of hypertonic NaCl solution has seldom been observed. These findings appear to differ from those reported by other investigators who have noted a marked, brief increase in the pulmonary artery pressure* (BINET & BURSTEIN, SEMLER, SHEPHERD & SWAN, READ, VICK & MEYER). In general, however, these authors used a dose of 1 ml/kg of a 15 % or 20 % solution while a solution of at the most 9 %, possibly with a slightly lower injection speed, was administered in the present material, hence the results are not directly comparable. SEMLER et coll. described reactions with a greatly increased pressure in the pulmonary artery, a fall in the systemic blood pressure to 25 mm Hg, apnoea, and cardiac rhythm irregularities. The magnitude of these reactions far exceeds anything the present authors were concerned in studying, in respect to the effect of both the contrast medium and the hypertonic saline solution. It is not clear whether the discrepancy may to some extent be regarded as due to a difference *in species*.

The observation that low molecular weight dextran is highly effective in preventing the occurrence of a pressure increase in the right ventricle after a Biligrafin injection would also appear to support the assumption that there may be a connection between erythrocyte aggregation and circulatory side effects. However, in view of the data recently published by READ, VICK & MEYER, regarding the protective effect of low molecular weight dextran against a rise in the pulmonary artery pressure due to a hypertonic NaCl solution, it is doubtful whether the explanation can be as simple as that. These investigators demonstrated in dogs that the protective mechanism appears to be due to an increase in blood volume rather than to specific inhibition of the erythrocyte aggregation.

The fact that the systemic blood pressure fall is not blocked by pretreat*ment with dextran of* low molecular weight would appear to contradict the hypothesis that there is a direct connection between red cell aggregation and systemic circulatory reactions. It would therefore seem as though the explanation of this pressure fall must, at least in part, be sought in some phenomenon other than restriction of the blood flow in the pulmonary circulation, caused by aggregated blood cells.

Adipiodon reduced the sedimentation rate of the red *blood cells both in vitro*

FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR PROF SOLVE WELIN) OF THE UNIVERSITY OF LUND MALMÖ ALLMÄNNA SJUKHUS MALMÖ SWEDEN

FALSE SIGNS OF THROMBOSIS IN LOWER LEG PHLEBOGRAPHY

by

TORSTEN ALMÉN and GÖRAN NYLANDER

The introduction of leg phlebography as a routine clinical method in the 1930 s raised the belief that thrombosis would no longer offer any diagnostic difficulties Phlebography of the lower leg was performed in the beginning with the leg horizontal (ANDERSON & PATTERSON BAUER HOUGHERTY & HOMANS DOS SANTOS LESSER & DANELIUS, BAKER SORENSEN) Later investigations showed however certain sources of error of this technique (GREITZ KJELLBERG LINDBLOM LOFSTEDT) These authors found that when the leg was horizontal there was incomplete contrast filling of the venous system because the high specific gravity caused the contrast medium selectively to fill the lowermost vessels Phlebography of the lower leg is now performed with the leg vertical in order to avoid such errors but even ascending lower leg phlebography in the vertical position produces diagnostic errors that have not received attention

This paper is concerned with a number of appearances that are liable to be misinterpreted as signs of thrombosis or postthrombosis and that have been noted during an investigation of the haemodynamics of the lower leg during rest and exercise (ALMÉN & NYLANDER)

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a b

Fig 1 a) Calf muscles contracted No filling of deep veins Superficial veins filled Collateral circulation via superficial veins (derivation) Appearances suggest deep thrombosis b) Same leg as in (a) but calf muscles relaxed Normal appearances

Material and methods The actual investigation consisted of 15 apparently normal lower legs of 12 volunteers and 26 lower legs of 21 subjects with varices The deep veins were normal in all of the legs studied

The technique was briefly as follows The subjects were examined with the lower leg placed vertically before a cut film changer Contrast medium, 40 ml Urografin 60 %, was injected into a dorsal vein of the foot The subjects were instructed to contract and relax their calf muscles alternately while 30 exposures were made at a rate of 2 to 3 per second Technical data 70–80 kV, 0 06 sec, 100 mA, FFD 100 cm

Findings

Three appearances liable to be misinterpreted as evidence of thrombosis or postthrombotic changes were observed and are hereafter referred to as 'pseudo thrombosis These occurred in normal veins but only during muscular con



Fg 2 *Left* calf muscl s *contracted* d ep veins segmentally compressed a d vo d of contrast m dium appearances suggest deep th ombosis *R ght* calf muscles rela ed normal app arances of deep v in and al es

Fig 3 Verified deep thrombos s Observe sim la its w th fig 2 left

traction *or* relaxation Pseudothrombosis was never observed in films exposed at the beginning *of the* examination when the muscles were relaxed In 9 of the normal legs and in 20 of those *with varices* pseudothrombosis was evident on one or more occ sions in the deep or superficial veins

Classific ition of pseudothrombosis

Type A There was either *complete* absence of filling of the deep veins or non filling of a short segment The *superficial* veins suggested the presence of a collateral circulation as if an organic *deep vein* obstruction were present the roentgenographic appearances resembled those seen in deep venous thrombosis (Figs 1 and 2)

Type B The deep veins had no demonstrable valves and their walls were irregular in outline The appearances were like those evident in recanalized deep thrombosis (Figs 4 and 5)



Fig 4 a) Calf muscles contracted outline of walls of deep veins irregular no valves demonstrable same appearances as in recanalized deep thrombosis b) calf muscles relaxed veins and valves of normal appearance

Type C Central filling defects in superficial varicose veins with valvular incompetence The appearances were similar to those associated with acute superficial thrombosis or thrombophlebitis (Fig 7)

Discussion

Type A This type of pseudothrombosis was seen only when the calf muscles were contracted It is well known that the limb muscles serve as 'the peripheral heart', when the calf muscles are contracted the deep veins are compressed, the degree varying with the extent of muscular contraction With maximal contraction all the contrast medium is expelled from that segment of the deep veins that lies under the calf muscles, and the leg is drained via the superficial veins ('cannaux de derivation LE DENTU, ALMEN & NYLANDER) This 'collateral circulation' persists as long as the deep veins are compressed and the



Fig 5 Same situation as in fig 4

appearances resemble those seen in deep venous thrombosis It is for this reason necessary to remember that normal deep veins may be completely compressed by calf muscle contraction

Type B This form was evident only during the act of contraction of the calf muscles The valves of a thrombosed vein are destroyed and when the latter is recanalized the reformed lumen is irregular The phlebogram of such a vein demonstrates no valves an irregular outline and often a spirally formed longitudinal wall structure The reason why normal deep veins are capable of producing a similar phlebographic appearance may be explained as follows

On phlebography performed during muscular rest the filling of the muscle veins is incomplete and often poor (If good contrast filling of these muscle veins is to be obtained their blood content must first be emptied by muscular contraction and then during relaxation the muscle veins will be refilled with contrast blood from the deep veins (ALMEN & NYLANDER)) On muscular contraction a large amount of unadulterated blood is expelled from the muscle

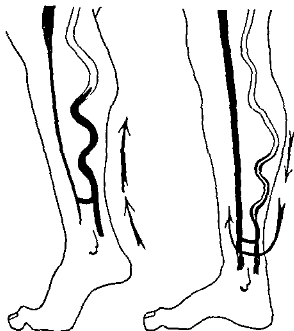


Fig 6 Diagram of drainage of lower leg in venous incompetence *Left* muscles contracted peripheral veins drained through superficial veins *Right* muscles relaxed retrograde flow through superficial incompetent veins

veins into the deep veins At the same time, contrast medium in the deep veins is driven rapidly in a proximal direction Owing to incomplete mixture between the contrast medium in the deep veins and the blood from the muscle veins, filling defects appear in the proximal deep veins and in the popliteal vein When the muscles are relaxed the valves are half open and readily distinguished During the act of muscular contraction, the rapid flow in the deep veins now forces their valves wide open and they are no longer demonstrable in the phlebograms In other words, the phlebogram then resembles that of a recanalized thrombus (Figs 4 and 5)

Type C This type of pseudothrombosis was encountered only during relaxation of the calf muscles and only in incompetent superficial veins When the muscles are relaxed, the blood flows in a proximal direction relatively slowly through the superficial veins and deep veins On muscular contraction the deep veins are compressed and the rate of flow in the superficial veins is increased as they now carry the entire venous drainage of the limb distal to the calf muscles ('canaux de derivation) On relaxation of the calf muscles, the deep veins and muscle veins are refilled from the distal deep veins and the superficial veins via the perforants If the valves of the superficial veins are incompetent, the blood will flow distally in these veins on muscular relaxation (Figs 6 and 7) When a varix filled with contrast medium empties rapidly (in about 0 5 sec) in this way and is filled from above with blood free from contrast medium, the evacuation of the contrast medium will not be complete A film of contrast medium will persist along the wall after the major portion of the



Fig 7 Superficial vein a) Muscles contracted centripetal flow homogeneous filling b) Muscles relaxed reversed flow filling defects simulating thrombosis

contrast medium has passed into the deep veins owing to a rapid axial flow in the lumen of the vessel and slower flow along its wall This results in a central filling defect *in the lumen* of the varix in other words it produces appearances resembling those seen in *thrombophlebitis* (Fig 7)

Conclusion

Several of the sources of error in the phlebographic diagnosis of venous thrombosis have been *eliminated* by examination of the leg in the vertical instead of the horizontal position *It is* essential to perform phlebography with the lower leg vertical However this change in position has not eliminated all sources of error Certain *hitherto* unknown phenomena appearing on contraction and relaxation of the calf *muscles* and producing appearances resembling those seen in venous *thrombosis must* now be recognized

It is hardly possible during phlebography for the examiner to exclude the possibility of the patient contracting the calf muscles, through pain for example in the event of such *contraction* pseudothrombosis is liable to occur

SUMMARY

Certain normal changes in the phlebographic appearance of the lower leg that may be misinterpreted as signs of venous thrombosis are described

ZUSAMMENFASSUNG

Bestimmte Veränderungen im phlebographischem Bild des Unterschenkels die leicht fälschlicherweise fur Venenthrombose gehalten werden konnten werden beschrieben

RÉSUMÉ

Les auteurs décrivent *certaines modifications normales des images phlébographiques de la* jambe qui peuvent être interprétées à tort comme des signes de thrombose veineuse

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ANGIOCARDIOGRAPHIC MEASUREMENTS IN CONGENITAL HEART DISEASE IN INFANCY AND CHILDHOOD

II Size of left atrium

by

HAKAN ARVIDSSON

The diagnosis of congenital heart disease in the conventional roentgenogram is based on changes in shape of the heart and the appearances of the great thoracic vessels The size of the left atrium plays an important *role in the* differential diagnosis as an example may be mentioned that the main difference between atrial septal defect and ventricular septal defect is enlargement of the left atrium in the latter Evaluation of the size of the left atrium is however often relatively difficult especially *in infants*

Several authors have discussed the size of the left atrium in congenital heart disease Most investigators agree that the left atrium is enlarged in ventricular septal defect (KJELLBERG *et coll* KEATS et coll MARQUIS TAUSSIG & WOOD et coll) KJELLBERG et coll observed that the enlargement was more marked in cases with low pressure in the pulmonary circulation than in the high pressure cases SINGLETON et coll found that the left atrial enlargement was proportional to the left to right shunt KEATS et coll reported 20 cases of ventricular septal defect 45 per *cent of* which had left atrial enlargement in the conventional roentgenogram Most authors consider the left atrium to be normal in size in tetralogy of Fallot The left atrium in aortic stenosis was

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Table 1

Survey of the material

Diagnosis	Number of cases	Average age (years)	Average m² BSA
Ventricular septal defect low pressure PA < 50 mm (VSDL)	25	4.8	0.78
Ventricular septal defect high pressure PA > 50 mm (VSDH)	10	1.7	0.40
Tetralogy of Fallot (ToF)	10	2.7	0.53
Aortic valvular stenosis (AoS)	6	9.3	1.10
Subvalvular aortic stenosis (SubAoS)	2	8.0	0.90
Aortic stenosis and insufficiency (AoSI)	1	7.0	0.95
Pulmonary valvular stenosis (PS)	15	7.2	0.91
Atrial septal defect (ASD)	2	9.0	1.08
Patent ductus arteriosus (PDA)	10	3.0	0.55
Ventricular septal defect and patent ductus arteriosus (VSD + PDA)	10	1.8	0.42
Normal cases (N)	11	12.0	1.50
Total	102	Mean 6.0	Mean 0.83

discussed by DOWNING who found left atrial enlargement in 7 out of 37 cases. The material consisted of valvular as well as subvalvular aortic stenosis and was not separated. KJELLBERG et coll. reported 23 cases of valvular and subvalvular aortic stenosis with left atrial enlargement in two cases only, in one of these there was subvalvular stenosis, in the other case there was no description of the lesion. Few observations of the left atrial size in pulmonary valvular stenosis are available but no enlargement has been described. The left atrium in atrial septal defect has been accepted as being normal in size (KJELLBERG et coll., and KRAEMER et coll.). The left atrium has been considered as enlarged in patent ductus arteriosus (EPPINGER & BURWELL, NEUHAUSER, NICHOL & BRANNAN, KJELLBERG et coll., KEATS & STEINBACH, DONOVAN et coll.). NICHOL & BRANNAN used the size of the left atrium as an aid in the differential diagnosis between patent ductus arteriosus and atrial septal defect.

Direct measurement of the left atrium was earlier employed in acquired heart disease (SOLOFF et coll., ARVIDSSON, 1958). Few direct measurements of the left atrium have been performed in congenital heart disease. An important paper, however, was published by BUNNELL, IKKOS, RUDHE & SWAN who studied the size of the left atrium and the left ventricle in 7 cases of coarctation of the aorta. Volume analysis of the left atrium in a paediatric material of congenital heart disease will be presented in this paper.

Material and Methods. The material was essentially the same as in the earlier study of the size of the aorta (ARVIDSSON 1962). However, some cases had to

Table 2

Survey of normal cases and pulmonary stenoses

Normal cases m BSA	LA_m ml	LA_{min} ml	Pulmonary stenosis m BSA	LA_m ml	LA_m ml
1 75	45	30	0 62	23	8
0 90	26	6	0 56	8	4
1 87	67	19	1 64	44	15
1 60	27	13	0 63	14	7
1 90	63	35	0 97	28	12
1 37	56	20	1 12	35	—
1 65	29	13	0 95	30	17
0 95	15	10	1 00	22	8
1 29	28	10	0 98	15	9
1 35	40	20	0 87	25	12
1 81	54	31	0 97	47	27
			1 22	41	17
			0 69	24	7
			0 97	26	13
			0 49	11	6

Normal cases regression equation LA_m 40 91 + 35 96 (BSA − 1 50) r = 0 60
Pulmonary stenosis regression equation LA_m = 26 60 + 30 38 (BSA − 0 91) r = 0 74
Common regression equation LA_m = 37 65 + 28 91 (BSA − 1 16)

Normal cases regression equation LA_{min} 18 82 + 20 86 (BSA − 1 50) r = 0 76
Pulmonary stenosis regression equation LA_{min} = 10 86 + 10 40 (BSA − 0 89) r = 0 64
Common regression equation LA_m = 14 36 + 11 41 (BSA − 1 16)

be rejected in the present study most of the atrial septal defects were examined in oblique projections which rendered volume determination impossible The left atrium was not filled in some other cases e g in left ventricular contrast injections and thoracic aortographies

A general survey of the material is presented in Table 1 in which the diagnoses the average age in the patient groups and the average body surface areas are given As in the previous study the ventricular septal defects were separated into two groups one with a pulmonary artery systolic pressure lower than 50 mm Hg (VSDL) and the other with higher pressures (VSDH) In the latter group it was considered possible that a right to left shunt could be present on exercise

The reader is referred to the previous publication in this series (ARVIDSSON 1962) in which the angiocardiographic technique was also described, for further information about the classification of the material The volume determination of the left atrium was carried out by the same method used in the study on mitral disease (ARVIDSSON 1958) The left atrial volume was calculated as an ellipsoid two of the ellipsoid axes were determined from the a p projection Correction for the geometric distortion due to divergence of the roentgen

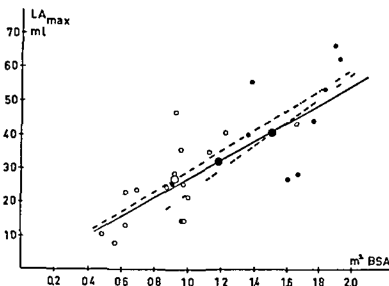


Fig 1 Left atrial maximum volume correlated to body surface area in normal cases (black symbols) and pulmonary stenoses (rings) The linear regressions are indicated as follows — — — — — — normal cases — — — — — — pulmonary stenoses ———— common regression For regression equations see Table 2 The large dots represent the averages within the materials

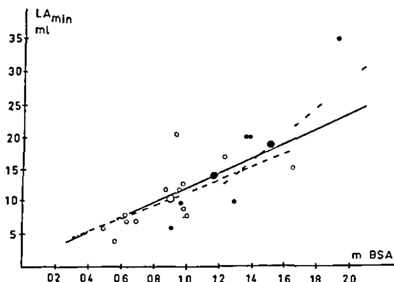


Fig 2 Left atrial minimum volume correlated to body surface area in normal cases (black symbols) and pulmonary stenoses (rings) Regression lines indicated as in Fig 1

rays was effected individually in each case according to well known principles The maximum (LA_{max}) and minimum (LA_{min}) volumes of the atrium were determined, the maximum volume was usually easy to evaluate, but the minimum was sometimes more difficult to arrive at, due to the fact that the outlines of the left atrium were difficult to distinguish in the films especially when the atrium was small and partly superimposed by the left ventricle The theoretical basis of the method of volume determination was discussed in detail earlier (ARVIDSSON 1958) BUNNELL et coll analyzed the error of the method in a dog material and found it to be small

The left atrial volume was correlated to body surface area in order to compensate for differences in body development The quotient pulmonary/systemic flow (p/s) in cases with left to right shunts was determined from the oxygen saturation values obtained with a Waters Conley cuvette oximeter

Results

A *The size of the left atrium in normal cases and in pulmonary valvular stenosis* The maximum and minimum volumes of the left atrium were correlated to body surface area in both the normal and pulmonary stenosis cases A survey of the results is given in Table 2 and Figs 1 and 2 As can be seen from the correlation coefficients, there was a reasonably good linear correlation between left atrial size and body surface area A co variance analysis showed that there was no statistical difference between the maximum volumes of the left atrium in the normal and the pulmonary stenosis groups A small difference existed however between the minium volumes in the two groups in spite of which was considered justifiable to treat the two materials as homogeneous and determine the common regressions as is shown by Table 2 and Figs 1 and 2 The common regression equations in Table 2 represent the normal correlations between left atrial volume and body surface area These equations however are somewhat inconvenient to use in daily routine and the approximate normal values for the left atrium are

LA_{m} ml $\approx 30 \times$ BSA in m^2
LA_{min} ml $\approx 10 \times$ BSA in m^2

These values are valid for young subjects further studies in adults have to be made in order to evaluate the normal size of the left atrium

The average heart rate within the two groups was 95 strokes per minute, which gives an average left atrial minute volume per m^2 of body surface area of 1 9 L This is considerably lower than the average cardiac index within the two groups of 4 8 L as determined from left ventricular volume calculations (The results will be published later in this series) The discrepancy between the volume changes of the left atrium and the left ventricle was discussed by the present author in 1958 and by BUNNELL et coll in 1961 The volume changes

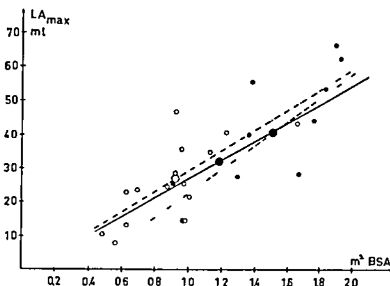


Fig 1 Left atrial maximum volume correlated to body surface area in normal cases (black symbols) and pulmonary stenoses (rings) The linear regressions are indicated as follows — — — — — — normal cases — — — — — — pulmonary stenoses ———— common regression For regression equations see Table 2 The large dots represent the averages within the materials

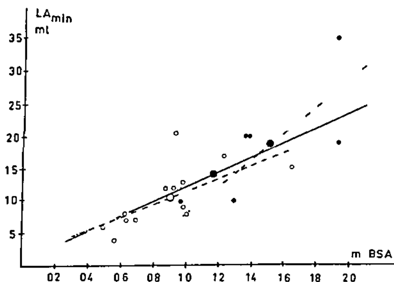


Fig 2 Left atrial minimum volume correlated to body surface in normal cases (black symbols) and pulmonary stenoses (rings) Regression lines indicated as in Fig 1

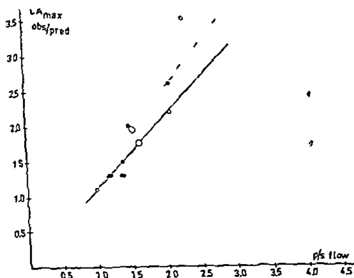


Fig 3 Left atrial maximum volume index (observed left atrial maximum volume divided by the predicted volume) correlated to the degree of left-to-right shunt expressed as pulmonary/systemic flow in ventricular septal defect. The predicted volumes were obtained from the regression for normal and pulmonary stenosis cases (Table 2). Black symbols indicate ventricular septal defect with low pressure and rings ventricular septal defect with high pressure. The regression lines given in this figure were calculated from cases with $p/s < 3$ (The symbol marked with 1 were not included in the calculated regression). Full line is the regression for VSDL and broken line the regression for VSDH. For regression equations see text

volume are given in Table 4. The correlation coefficients improved by the introduction of the second parameter (the shunt) in all diagnostic groups indicating that the size of the shunt influences the size of the left atrium. A co-variance analysis between the materials showed that a small difference between the diagnostic groups existed. It is relatively difficult to evaluate the importance of the two *independent* parameters in the regression equations in Table 4 and another method was therefore used to demonstrate the relationship between left atrial size and the degree of shunting.

From the common regression equation *obtained* in the normal and the pulmonary stenosis cases (Table 2) a predicted left atrial volume (LA_{pred}) was calculated in every case of left *to right shunt*. This was done for the left atrial maximum volume only. The observed left atrial volume (LA_{obs}) was divided by LA_{pred}. The quotient LA_{obs}/LA_{pred} was correlated to the quotient pulmonary/systemic flow as demonstrated *in Fig 3*. The degree of linear correlation was reasonably good within the two groups of ventricular septal defect (VSDH $r = 0.73$ and VSDL $r = 0.53$). However the correlation

Table 3

Survey of the cases of left to right shunts

Diagnosis	m² BSA	LA_{max} ml	LA_{min} ml	Flow p/s	Diagnosis	m² BSA	LA_{max} ml	LA_{min} ml	Flow p/s
Ventricular	0 82	28	12	1 4		0 26	11	5	1 9
septal de	0 82	29	10	1 4		0 55	24	12	1 4
fect, low	0 74	36	20	4 0		0 58	32	18	2 3
pressure	0 27	24	7	2 4		0 40	37	18	2 3
	1 15	49	17	1 4		0 23	7	4	1 3
	0 91	48	25	2 2		0 41	37	21	4 3
	0 67	38	18	2 3					
	0 42	14	5	1 3	Patent ductus	0 38	14	7	1 5
	0 72	31	13	1 6	arteriosus	0 34	14	9	4 0
	1 07	34	11	1 2		0 30	13	6	1 6
	0 85	27	10	2 4		0 77	28	8	2 1
	1 70	55	33	1 2		0 81	60	30	4 5
	0 54	28	13	3 0		0 46	37	18	5 0
	1 03	42	24	1 4		1 01	38	12	1 4
	0 49	22	13	2 1		0 42	16	10	1 5
	0 74	60	20	2 4		0 50	37	17	5 0
	0 12	29	10	2 1		0 49	21	10	2 2
	0 62	24	12	1 3					
	0 62	35	15	1 5	Ventricular	0 87	60	40	10 5
	0 50	32	14	4 0	defect + pa	0 46	20	14	[illegible]
	0 86	35	18	1 3	tent ductus	0 61	39	16	1 1
	1 24	47	16	1 2	arteriosus	0 23	17	10	3 2
	0 73	19	10	1 6		0 30	6	4	2 2
	0 88	33	17	1 2		0 28	14	6	3 5
						0 33	21	15	2 6
Ventricular	0 70	21	10	1 0		0 32	12	[illegible]	1 1
septal de	0 27	9	7	1 0		0 50	26	14	8 5
fect high	0 36	28	12	1 3		0 22	13	7	2 0
pressure	0 23	33	8	2 1					

of the left atrium do not represent the output of the heart because the atrium is never a closed chamber during diastole, part of the blood is transported directly from the pulmonary veins into the left ventricle

B *The size of the left atrium in cases with left to right shunts* The observations within the diagnostic groups with left to right shunts are given in Table 3 It is obvious that the left atrium is relatively larger in these groups than in the normal cases and the pulmonary stenosis group The linear correlation between left atrial size and body *surface area in the left to right shunt groups* was reasonably good but it appeared as if the size of the left atrium was governed not only by the body surface area but also by the degree of shunting

The quotient pulmonary/systemic flow was thus introduced as a second, independent parameter The regression equations and correlation coefficients obtained within the different diagnostic groups for the maximum left atrial

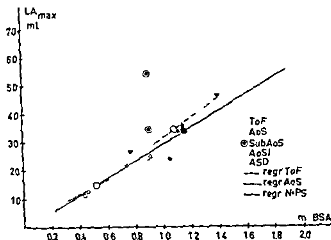


Fig 4 Left atrial maximum volume n cases of tetralogy of Fallot aort c alvular stenosi aort c s bvalvula stenosis and atrial septal defect For regress on equat ons see text The common regres on fo the normal cases and pulmonary stenoses is drawn for comparison p rposes The regres ions fo tetralogy of Fallot and aortic tenosis do not d ff r s gnificantly f om the normal regression The two ca e of atrial septal defect l e with n normal limits Two cases of s baortic stenosis had enlarged at ia

although in cases with patent ductus the relationship was less obvious Since the minimum volume of the left atrium is of less interest, the regression equa tions and correlation coefficients will not be given

C *The si e of the left atrium in tetralogy of Fallot aortic disease and atrial septal defect* The left atrial maximum volume was analyzed according to the same principles as in the previous diagnostic groups in 10 c ses of tetralogy of Fallot

There was also a linear correlation between the LA_m and the body surface area in this condition The regression equation was

$$\text{T o F } LA_m = 22\,40 \text{ BSA} + 1\,90 \qquad r = 0\,72$$

The regression did not differ significantly from the one obtained in pulmonary stenosis and normal cases (see Fig 4)

The 6 cases of aortic valvular stenosis gave the following regression equation

$$\text{A o S } LA_m = 33\,67 \text{ BSA} - 4\,12 \qquad r = 0\,74$$

The regression coefficient is greater than within the normal and pulmonary stenosis cases However the small material does not permit a definite conclu sion in this respect even though it appears probable that some enlargement is present in aortic valvular stenosis (Fig 4) Two cases of subvalvular aortic stenosis were plotted in Fig 4 and had definitely enlarged atrias as compared

Table 4

Linear correlation between LA_{max} (Y) and body surface area (X_1) and the quotient pulmonary/systemic flow (X_2) in cases of left to right shunts

Group	Equation	obs	r
VSDL	$Y = 34.13 + 29.87 (X_1 - 0.78) + 4.52 (X_2 - 1.91)$	24 obs	r = 0.73
VSDH	$Y = 22.20 + 41.13 (X_1 - 0.40) + 7.07 (X_2 - 1.81)$	10 obs	r = 0.80
PDA	$Y = 27.80 + 48.22 (X_1 - 0.55) + 5.95 (X_2 - 2.88)$	10 obs	r = 0.93
VSD + PDA	$Y = 22.80 + 67.05 (X_1 - 0.42) + 0.62 (X_2 - 3.69)$	10 obs	r = 0.94

coefficients were far from 1.00, which would be the case if the left atrium dilated directly proportional to the shunt. A closer analysis showed that the relatively low correlation was mainly due to the cases with large left to right shunts in which the left atrium was not enlarged in proportion to the shunt. All cases with a p/s quotient higher than 3 were excluded in order to analyze the relationship in cases with moderate and small shunts (as in Fig. 3). By this operation the correlation coefficient is VSDL increased to 0.70 while the VSDH remained unchanged at 0.73 (only one case was excluded).

The regression equations were

VSDL $p/s < 3$ $(n = 21)$, $Y = 0.95\,X + 0.06$ $r = 0.70$

VSDH $p/s < 3$ $(n = 9)$, $Y = 1.29\,X + 0.02$ $r = 0.73$

$Y = LA_{obs}/LA_{pred}$, X = pulmonary/systemic flow

The correlation coefficients within the two groups indicate that the left atrial enlargement is directly proportional to the shunt in ventricular septal defects with $p/s < 3$. The left atrium is relatively smaller above this degree of shunting. It is obvious when the two regression equations are compared that the enlargement of the left atrium is as great in the high pressure group as in the cases with lower pulmonary pressure. This is in contradiction to the statement by KJELLBERG et coll. who found more marked left atrial dilatation in ventricular septal defects with low pressure.

The correlation between LA_{max} and body surface area and shunt in the groups with a left to right shunt where a patent ductus arteriosus was present is given in Table 4. The left atrial size was also affected in these groups by the degree of shunting although an analysis similar to the one performed in the ventricular septal defect groups revealed that the correlation was not as good when a patent ductus was present. The reason for this is obvious. It is very difficult to determine the p/s quotient in cases with patent ductus arteriosus because the oxygen saturation values in the pulmonary artery are unreliable. The results are too dependent on the location of the catheter at the time of sampling.

An analysis of the left atrial minimum volumes gave the same general results as for the maximum volumes. A linear correlation between the left atrial minimum volume and the shunt in ventricular septal defects was evident

emptying during ventricular systole since the mitral valve is closed and the blood accumulating from the lungs will consequently distend the left atrium In atrial septal defect on the other hand the left atrium can empty into the right atrium at any phase of the heart cycle This means a more or less continuous flow through the atrial septal defect with an increased systolic load on the right atrium but not on the left

It was evident in the present study that the linearity between left atrial enlargement and shunting was not very good in the cases with marked left to right shunts This was probably due to the elastic properties of the left atrium when a certain dilatation is reached the atrial wall offers more resistance to further dilatation and the pulmonary veins take part of the volume load

It was found that the left atrium was probably somewhat enlarged in aortic valvular stenosis as compared with the normal material and definitely enlarged in subvalvular aortic stenosis It is well known that the left atrium is sometimes enlarged in diseases with increased pressure and/or volume load on the left ventricle as in aortic valvular stenosis and insufficiency, coarctation of the aorta and systemic hypertension The observations are however mostly made in adult subjects where time has elapsed as to cause development of an increased end diastolic pressure in the left ventricle The cases of aortic valvular stenosis in the present material were usually relatively mild with moderate systolic gradients over the aortic valve and consequently the burden on the left ventricle was only moderately increased The subvalvular stenoses were of the hypertrophic type of severe degree resulting in a marked left atrial enlargement The observations are in agreement with the statements of KLATTE TAMPAS CAMPBELL & LURIE who found a higher degree of left atrial enlargement in subvalvular aortic stenosis than in the valvular type

SUMMARY

The left atrial maximum and minimum volumes were determined from angiocardiographies in 102 cases of different types of congenital heart disease The left atrial size was correlated to body surface area A linear regression was observed between the two parameters in all the diagnostic groups The left atrium was larger in cases with left to right shunt than in those without a shunt and the enlargement was generally proportional to the degree of shunting

ZUSAMMENFASSUNG

Das Maximal und Minimalvolumen des linken Vorhofes wurde in 102 Fallen von angeborenen Herzfehlern verschiedener Art durch Angiokardiographie bestimmt Die Grosse des linken Vorhofes wurde mit der Korperflache inbezug gebracht Ein linearer Abfall der beiden bezuglichen Grossen wurde in allen diagnostischen Gruppen festgestellt Der linke Vorhof war grosser in den Fallen in denen ein Shunt von links nach rechts vorlag als in den Fallen ohne Shunt und das Mass der Vergrösserung entsprach im allgemeinen der Grosse des Shunts

with the other cases without shunts One case of combined aortic stenosis and insufficiency was within the normal limits Unfortunately it was only possible to measure two cases of atrial septal defect, *the left atrial size in these two cases* was within normal limits (Fig 4)

Discussion and Conclusions

The aim of the present study was to make an objective angiocardiographic analysis of the size of the left atrium in congenital heart disease The results were in agreement with generally accepted ideas based on conventional film interpretation It is, however, of importance to take into consideration one source of error in the judgment of the left atrial size from conventional films As was demonstrated by the present study the volume changes of the atrium during the heart cycle are considerable Since the conventional films are usually not triggered but exposed at random, the left atrium may have any volume between the maximum and minimum at the time of exposure This is without doubt the reason for the difference in left atrial size at repeated roentgen examinations at short intervals An earlier study on mitral disease (ARVIDSSON 1958) disclosed that the volume of the left atrium was relatively small during ventricular diastole and only reached its peak volume during a very short phase at the end of ventricular systole There is thus considerable likelihood that the left atrium appears too small at routine chest roentgenography It is of value for a precision diagnosis from conventional films to use an ECG *triggered exposure so that films exposed at the end of systole may be obtained*

A reasonably good linear correlation was found within the present material *between the left atrial volume (maximum and minimum)* and body surface area in all the diagnostic groups analyzed There was very little difference in *the regression line for the pulmonary stenosis group* and *the normal cases* The two materials were put together and formed a normal material with a regression suitable for prediction of the normal left atrial size *from body surface area*

The left atrium was larger than within the 'normal' material *in the diagnostic groups* with left to right shunts at the ventricular and aortic levels The correlation between left atrial size and body surface area *in the shunt materials* could be improved by introducing the degree of shunting as a second independent parameter It was thus demonstrated *that the left atrial volume was influenced* by the degree of shunting This finding was not unexpected, in fact it has been observed earlier by several authors The dilatation is caused by the increased flow in the lesser circulation putting an increased volume load on the left atrium The puzzle is why the left atrium is not affected *in the same* way in cases with shunts at the atrial level The reason for this was discussed inter alios by KJELLBERG, RUDHE, MANNHEIMER & JONSSON *The left atrium in* ventricular septal defect and patent ductus arteriosus has no possibility of

BOOK REVIEWS

LA GROSSE TUBÉROSITÉ DE L ESTOMAC ETUDE CLINIQUE ET RADIOLOGIQUE Par T Schops 574 pages et 475 figures Doin & Cie Paris 1961 Price 125 NF

A large number of case reports and excellent roentgenograms form the material of this book Schops s definition of the term forms (la grosse tubérosite) may be open to some criticism but as it is based upon the appearances evident in the living subject it is at least practical The author gives a complete and detailed description of the mucosal relief pattern and explains normal appearances that are often mistaken for ulcer niches Technical details of the roentgenologic examination of the upper part of the stomach are described for each condition The author particularly insists that in the search for a growth a moderate amount of air should be swallowed by the patient that a technique of exposure ordinarily confined to the examination of the lungs should be employed and that the patient should be examined in both the erect and recumbent positions with frontal lateral and oblique projections after the administration of a small quantity of barium emulsion

Every condition that may be encountered in the upper part of the stomach excepting those that occur only in children are included Each is considered from the clinical and roent genologic viewpoints typical and rare forms as well as development and complications being described The parts of the book that deal with differential diagnoses are of particular interest for the practical difficulties are not avoided but an attempt is made to solve them As examples may be cited the differentiation of an ulcer from a diverticulum or of a tumour from pressure from without by a neighbouring organ (left lobe of the liver ectopic spleen enlarged lymphatic ganglia and the diagnosis of two conditions that may be present in association such as a hiatus hernia and carcinoma ulceration or a benign growth The illustrations of each condi tion are grouped in the roentgenologic section in an order that is sometimes different from that of the clinical case reports an arrangement that is probably justified although one that the reader may find a trifle inconvenient

The reproductions of th films are good on the whole and they are of adequate size some ha e be n retouched rather crudely although this does not detract from their value The large collection of illustrations many accompanied by tracings form an atlas of la grosse tubéro sité A bibliography of 22 pages an alphabetical list of authors and a subject index are included at th end of the book

It does not appear to th reviewer that the employment of image intensification or cineroent genograph coul l add materially to the investigation or alter the author s conclusions

This is a practical useful and indeed an original book that can be warmly recommended For ign eaders in particular will appreciate the simple and clear language of the relatively short text

J Roulleau

RÉSUMÉ

Les volumes maximum et minimum de l oreillette gauche ont été calculés d après les angiocardiographies dans 102 cas de divers types de cardiopathies congénitales Une corrélation a été établie entre le volume de l oreillette gauche et la surface corporelle On a observé une régression linéaire entre ces deux paramètres dans tous les groupes de diagnostics L oreillette gauche est plus volumineuse dans les cas de shunt gauche droite que dans ceux sans shunt et l augmentation de volume est en général proportionnelle au degré de shunt

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BRONCHOGRAPHIE CLINIQUE Par Etienne Bernard et Bernard Gamain 196 pages 132 figures 29 schemas Masson Paris 1961 Price 52 NF

The assertion in the introduction that la bronchographie prolonge la bronchoscopie et va plus loin is well supported by the main text of this well written book

The work deals with bronchography and the clinical aspects of diseases of the bronchial tree It contains numerous schematic drawings and most of the roentgen films are of high quality The treatment of the subject is clear and concise the section on technique being particularly exhaustive and instructive — for beginners as well as for others The reviewer notes with satisfaction that the authors expressly state that so-called alveolar or bronchiolar filling reveals nothing but an incorrect technique Unfortunately this section does not make it clear that premedication with barbituric preparations is necessary when tetracaine is used as a local anesthetic These preparations reduce the toxicity of tetracaine an effect that must nearly always be utilized seeing that a more or less maximal dose of tetracaine has usually to be given to achi ve satisfactory anesthesia

It might perhaps have been advisable in the chapter on the different contrast media to say a few words about their disadvantag s In particular the risk of foreign body granuloma formation should have been mentioned especially as Lipiodol with added talc or silicate sub tances (bentone) in addition to water soluble preparations are discussed the risk of foreign body granuloma is admittedly mentioned by the authors although only *in passing* and in another connection

The clinical section is somewhat laden with syndromes and proper names in the traditional French manner but in spite of this and the other minor faults that *have be n mentioned this book* on bronchography is an excellent one and one that can be warmly recommended

Uno Norlin

LEHRBUCH DER RONTGENDIAGNOSTISCHEN TECHNIK FUR RONTGENASSISTENTINNEN UND ARZTE Von N F Zimmer und Marianne Brossy 578 Seiten und 739 Abbildungen Springer Verlag Berlin 1962 Price 86 DM

This textbook of 578 pages is intended to be of help in the daily work of both radiologist and technician The introductory s ction contains chapters on phy ics and electricity roentgen rays and roentgen tubes on the principles of roentgenographic and roentgenphotographic techniques, as well as on the care of the patient About two-thirds of the book together with detailed photographs and drawings are devoted to positioning in radiography The final chapter offers advice on treatment when complications arise during examinations a short list of terms is included

The fundamentals of physics are well illustrated and easy to understand and a list of physical definitions is of great value The way in which the difference between radiations of various energies is described does not however seem to be fully adequate

The generation of roentgen rays and basic electrical questions are presented in detail with most instructive drawings but the elements of photography which are also important are not satisfactorily described The theory of tomography is outlined but the method is not des ribed in deta l Various methods of processing of roentgen films are considered There is a too brief discussion on contrast levelling but the logetronic method is mentioned

PEDIATRIC X RAY DIAGNOSIS By John Caffey 4th edition 1236 pages and 1536 illustrations Year Book Medical Publishers Chicago 1961 Price 32 dollars

Caffey s well known textbook of paediatric roentgen diagnosis now appears in a fourth edition after an interval of five years Some of the sections are more comprehensive than in previous editions and a large number of new items taken from various branches of paediatrics, reflect recent developments in this field As examples of such items may be mentioned accelerated maturation of the sternum associated with congenital heart disease congenital adenomatoid malformation of the lung pneumocystis carinii steroid induced atrophy and regrowth of the thymus corrected transposition of the great arteries obstructing meconium plugs the pelvis in mongolism and achondroplasia congenital constrictions and angulations in the extremities multiple sclerotic osteogenic sarcomas aneurysmal bone cysts and idiopathic chronic hypercalcemia The new sections are written in the same clear concise didactic style as in all the previous editions and the work contains 269 new figures divided up into 644 prints including several diagrams and schematic drawings The majority of the illustrations are of high quality Dr Caffey has continued with his old system of describing the roentgenographic findings against the background of the clinical manifestations and of emphasizing information that can be gained preferably from simple uncomplicated roentgen examinations Certain surgical problems relating to roentgen diagnosis are consequently treated rather summarily although this does not detract from the value of an excellent book which still holds its position as the leading work in its particular field

More than 450 new references which seem mainly to have been selected from the anglo saxon literature have been added

The book will be of great value both to paediatricians and to radiologists working in the paediatric field

Ulf Rudhe

DIE WIRBELSAULENLEIDEN UND IHRE DIFFERENTIALDIAGNOSE 3 erweiterte Auflage Von J F W Brocher 528 Seiten und 349 Abbildungen G Thieme Stuttgart 1962 Price 128 DM

The first edition of this work which appeared in 1953 was confined to tuberculosis of the spine and its differential diagnosis In a second edition published in 1959 the material had been entirely revised and extended and included spinal diagnosis in its entirety The third edition now under review contains a new chapter dealing with fractures and in addition certain changes have been made in the old chapters The book in its present form gives a complete presentation of roentgen diagnosis in diseases of the spine Myelography is only briefly mentioned

This book is the work of one man and in consequence the chapters are harmoniously balanced to form a complete picture As the illustrations derive mainly from the author s own practice he has been able to describe the clinical signs and present confirmations of the diagnose The biography comprises 28 pages and the illustrations are excellent The author deserves a compliment for a solid comprehensive and instructive work

Folke Knutsson

ACTA RADIOLOGICA

OFFICIAL ORGAN OF THE RADIOLOGICAL SOCIETIES OF DENMARK FINLAND NORWAY AND SWEDEN

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ANGIOGRAPHY IN TUBERCULOUS MENINGITIS

by

TORGNY GREITZ

Cerebral angiography has provided the basis for an intra vitam study of stenosing processes of the cerebral vessels These changes may be functional or organic It has been revealed during the last decade that spastic contractions of the cerebral arteries in subarachnoid haemorrhage are not rare phenomena (ECKER & RIEMENSCHNEIDER 1951 NORLÉN 1953 LINDGREN 1954) Similar changes are also encountered following head trauma (GREITZ & LINDGREN 1961 FREIDENFELT & SUNDSTROM 1963)

Atherosclerosis is the most common cause of arterial stenosis and changes due to this disease are frequently seen in angiography Cerebral emboli are occasionally diagnosed angiographically Tumors especially when extracerebral may compress an intracranial artery and by growing around it, cause concentric narrowing of its lumen (LINDGREN 1954, TÖNNIS & SCHIEFER 1954, ISFORT 1961) TOLOSA (1954) described a case with a periarteritic process of the carotid artery, which at the angiographic examination had a segmentary constriction of the siphon Narrowing of the carotid artery in luetic arteritis was described by DECKER (1960) PLESKOT & KRIVKA (1961) claimed to have found a similar reduction in caliber of all the cerebral arteries in cases of endangitis obliterans and in periarteritis nodosa observed irregular constrictions and multiple miliary aneurysms As there are only few reports on angiographically diagnosed stenosis

From the Roentgendiagnostic Department (Director Prof T Greitz) Umeå Medical School Sweden Submitted for publication 16 November 1962

All the roentgenograms are reproduced as positives and not as negatives. This appears to be a drawback in a book intended to be an elementary one, for a roentgen film positive is never encountered in daily routine. Only a few of the film faults that ought to be avoided are mentioned.

The instruction in positioning is better than in any earlier work. The criterion of a perfect roentgenogram is given and common mistakes in positioning are exemplified. The anatomical drawings are most informative and as a whole this important part of the book is very well presented. It is, however, surprising to find that correct positioning of the skull and angulation of the beam are achieved in a somewhat primitive manner by means of pillows, wooden boxes, plates and shelves; the Lysholm skull table produces better results more easily and has been used by radiologists for more than 25 years. Some unusual methods are described but most of the techniques presented are well known.

Arthrography of the knee, an examination not without importance, is described but not illustrated. On the other hand the illustrations that accompany the descriptions of other arthrographic examinations are, at their best, indifferent.

The advice to technicians regarding sanitation and their toilet, such as the care of nails and hair, might well be offered elsewhere than in this book. The same might be said about the recommendations for cooperation with the staff.

Ove Mattsson

TRAITÉ DE TECHNIQUE CHIRURGICALE. Tome III. Crâne, encéphale, rachis, moelle. Fasc. 1. Généralités — Méthodes d'exploration. Deuxième édition entièrement refondue. Par M. David, J. P. Constans, P. Deligné, G. Ruggiero, J. Talairach et P. Tournoux. 698 pages et 532 figures. Masson et Cie, Paris 1961. Price: 120 NF (broché), 132 NF (cartonné).

The larger part of this volume of the great French textbook dealing with examination and operation techniques in surgery is devoted to a review of neuroradiologic examination methods, including stereotaxis and the use of radioactive isotopes in the investigation of the central nervous system. It is thus of great interest to neuroradiologists.

The chapter on roentgenologic examination methods, which occupies more than half of the whole volume, has been written by G. Ruggiero. The material is presented in a clear and readily accessible form, the history of each method as well as its more recent modifications being treated in considerable detail. The author's praiseworthy efforts to achieve completeness sometimes produce rather strange results, however; for example he quotes the extraordinary view that only positive contrast media permit a differential diagnosis between supra- and infratentorial tumours. One often feels when reading the book that a more definite expression of opinion by the author regarding the advantages and disadvantages of the different methods would have been of value. In the account of the different methods for myelography, for instance, he confines himself for the most part to an historical review and refrains from making any contribution to the current controversy on this subject. He sometimes avoids a discussion with a statement such as "a neuroradiologist should not be a specialist in one particular technique but should be a master of them all". (There would appear to be no reason in being a specialist in a technique or method which, without offering any particular advantages, involves increased risks to the patient or must obviously lead to incorrect results.)

Despite these reservations Ruggiero's presentation may be described as an excellent introduction to neuroradiologic techniques. The different sections, with only one or two exceptions, are well proportioned and the book contains a large number of high class photographs and drawings which, from a didactic standpoint, are well chosen. It is doubtful whether a more all round and exhaustive account of neuroradiologic methods is available today.

Torgny Greitz

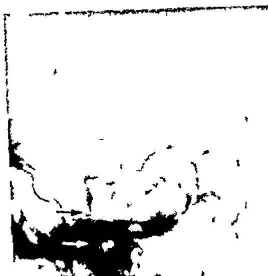


Fig 2 Same case as in fig 1 Vertebral angiography The basilar artery is shifted posteriorly in its entire length (In the pa projection which is not shown here the middle cerebral artery and its branches were partly filled with contrast medium via the right posterior communicating artery)

Case reports

Case 1 Woman aged 30 years with an old calcified tuberculous process at the apex of the right lung complaining of continuous headache which began 10 days before admittance Body temperature had been between 37 5 and 39 5 C On clinical examination there was evidence of nuchal rigidity The cerebrospinal fluid showed increased protein a decreased sugar content and a moderate pleocytosis with chiefly mononuclear cells Slight papilledema and IV nerve palsy developed later The patient continued to be febrile despite treatment with isoniazid streptomycin and paraaminosalicylic acid

Bilateral *carotid angiography* and *vertebral angiography* were performed six weeks after the onset of symptoms to rule out the presence of a cerebral abscess Marked constriction of the carotid siphon mainly in its intradural part was evident on both sides and the proximal portions of the anterior and middle cerebral arteries were also slightly narrowed (Fig 1) The right pericallosal artery was partly filled from the left side The circulation time (determined according to GREITZ 1956) was 5 seconds and thus not prolonged The central veins were displaced as in cases of slight dilatation of the lateral ventricles The arteries within the anterior part of the Sylvian fissure on both sides seemed to be displaced slightly superiorly Backward displacement of the whole of the basilar artery was demonstrated by vertebral angiography (Fig 2) A small amount of contrast medium passed via the right posterior communicating artery over into the carotid siphon and the middle cerebral artery on the same side indicating a collateral circulation from the vertebral to the carotid system

Six months after the angiographic examination the patient was discharged with some loss of hearing as the only sequela Meanwhile a guinea pig inoculation turned out to be positive

Case 2 Woman aged 36 with a previous history of bilateral pulmonary tuberculosis Two weeks prior to admittance she had increasing fever and headache On examination there was nuchal rigidity and left-sided VI nerve palsy The cerebrospinal fluid showed increased protein content a decreased amount of sugar and pleocytosis with 9 mononuclear cells

Carotid angiography (left) was performed four weeks after the beginning of symptoms and demonstrated very slight narrowing of the intradural part of the carotid siphon (Fig 3) this

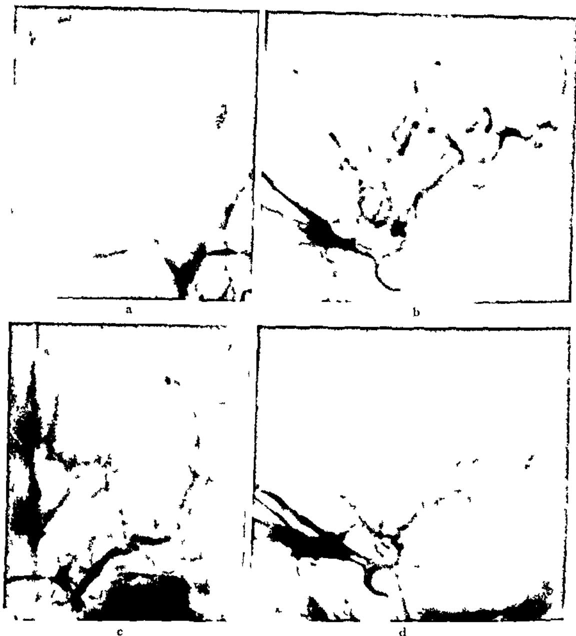


Fig. 1. Case 1. Angiography of carotid artery. a) and b) Right side, c) and d) left side. Practically the same findings on both sides. Concentric narrowing of intradural part of carotid siphon, proximal parts of anterior and middle cerebral arteries also appear slightly narrowed. The pericallosal artery runs in a wider curve than normally due to ventricular dilatation. Slightly elevated arteries in anterior part of *Sylvian fissure*.

of cerebral vessels caused by infectious processes, it seems worthwhile to describe the angiographic findings in 4 cases of tuberculous meningitis.

Cerebral angiography in these cases was performed in order to rule out a brain abscess or a tumor, as the diagnosis at the time of the examination was not fully established and in one case not even anticipated.



Fig 4 Case 3 Angiography of the right common carotid artery The intradural part of the siphon the anterior cerebral artery and the proximal part of the middle cerebral artery are narrowed and thread like in appearance

fever On examination she was comatous and had nuchal rigidity and spasticity of both legs with bilateral extensor plantar responses No papilledema was noted As an expanding process of the posterior fossa with raised intracranial pressure was considered possible lumbar puncture was withheld (Fig 7a) A roentgen examination of the skull revealed separation of the sutures

Vertebral angiography demonstrated depression of the tonsillar branches of the posterior inferior cerebellar artery indicating tonsillar herniation (GREITZ & SJOGREN 1963) and changes of the central branches of the posterior cerebral arteries as in hydrocephalus (GALLOWAY GREITZ & SJOGREN 1964) The presence of an expanding lesion in the posterior fossa could not be fully established Local widening of a branch of the left posterior cerebral artery was evident This was considered definitely pathologic and was difficult to explain by a tumor of the posterior fossa Angiography of the carotid artery was not performed in this case

One week after the angiographic examination the patient suddenly died At autopsy there was evidence of tuberculous basal meningitis with marked internal hydrocephalus and depression of the tonsils The meninges on the surface of the brain were clouded and thickened and at the base of the brain a typical greenish gelatinous exudate was present in the cisterns (Fig 7b)

Microscopic examination confirmed the diagnosis of tuberculous meningitis Inflammatory changes were found in all the arteries at the base of the brain and especially in the small arteries intimal swelling which caused a concentric narrowing of the lumina of the vessels No obvious intimal swelling was observed on microscopic examination of the vertebral artery in which no alterations had been noted at the angiographic examination (Fig 8) The arterial changes observed in this case were typical of tuberculous vasculitis

Comment The author had the opportunity in 1957 at the Edward Mallinckrodt Institute of Radiology St Louis U S A of making his first angiographic observation on tuberculous meningitis in a case which had an extraordinarily marked constriction of both carotid siphons This case has not been published



Fig. 3. Case 2. a) Small irregularities in the vessel wall with insignificant narrowing of the lumen of proximal part of middle cerebral artery. b) Intradural part of siphon is narrow; this change is however too small to be considered definitely pathologic.

change could, however, not be considered definitely pathologic. There was also a minute and slightly irregular narrowing of the proximal portion of the middle cerebral artery. No other abnormalities were noted. The circulation time was 4.5 seconds.

Even in this case the guinea pig inoculation was positive. The patient was discharged after four months stay in hospital.

Case 3. Woman aged 30 years who was admitted to the gynecologic department with abdominal pain and fever probably due to acute salpingitis. She was treated with various antibiotic drugs without any noticeable effect. One month after admittance nuchal rigidity and diplopia were noted and lumbar puncture revealed increased protein and decreased sugar content, pleocytosis with 69 mononuclear cells out of 103 cells per mm.

Right sided *carotid* and *vertebral angiography* were performed to eliminate a brain abscess. At vertebral angiography a retrograde flow in both posterior communicating arteries producing a filling of both the pericallosal arteries and of the right middle cerebral artery could be demonstrated (Figs. 4 and 5). These findings made it possible to predict a narrowing of the carotid siphon on both sides. This assumption was confirmed as far as the right side was concerned in that the carotid siphon was extremely narrow at subsequent right sided carotid angiography. The intradural part of the siphon, the anterior cerebral artery and the proximal portion of the middle cerebral artery were however thread like (Fig. 6). The circulation time exceeded 9 seconds and was consequently extremely prolonged.

The guinea pig inoculation was positive as in the two previous cases. The patient is still in hospital 5 months after the angiographic examinations; she is in bad shape and suffers from mental confusion.

Case 4. Girl aged 4 years with a history of transient weakness in the left arm half a year prior to admission. She had had increasing disorientation and apathy and occasional attacks of



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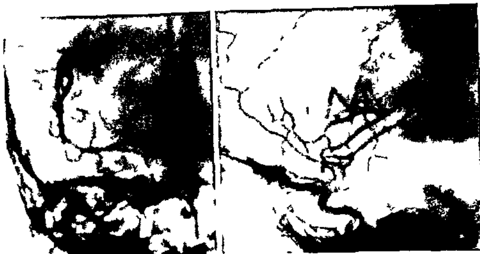


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Fig 5 Same case as in fig 4 Vertebral angiography The carotid siphon is filled especially on the right where the middle cerebral artery (↔) is clearly seen via both posterior communicating arteries (→) Both pericallosal arteries are filled



Fig 6 Schematic drawing showing appearances of siphon in Cas 3 (left) and common appearances in marked cerebral vasospasm (right) There is a conical but less constricted area in the upper part of the spastic siphon

Discussion

The following causative factors should be considered regarding the nature of the narrowing seen in the intradural part of the carotid siphon and its main branches generally increased intracranial pressure, locally increased pressure within the basal cisterns, spastic contractions of the arteries and tuberculous vasculitis

Increased intracranial pressure may be the cause of impaired cerebral circu lation More or less choked discs were present in Cases 1 and 3 both with the most marked vascular constriction Such arterial changes are, however, not found even with considerably increased intracranial pressure when due to other factors such as tumor or aqueduct stenosis The inhibition of the circu

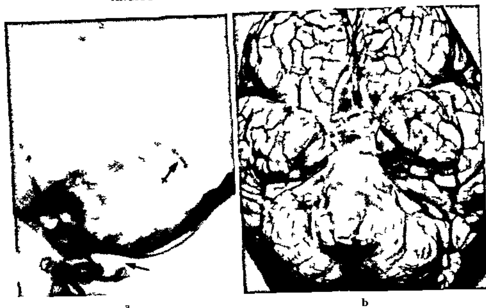


Fig 7 Case 4 a) Vertebral angiography No posterior shift of basilar artery which does not seem to be constricted The main trunk and tonsillar branches of posterior inferior per callosal artery are displaced below the foramen magnum (→) A local dilatation of one of the branches of the posterior cerebral artery evident (↔) b) Specimen The base of the brain with all the main cranial nerves and arteries are embedded in tuberculous tissue which completely fills the cisterns

lation seen at angiography in comatose patients with tentorial herniations is very marked so that no contrast medium passes over into the cranial cavity (RIISHEDE & ETHELBERG 1953 LOFSTEDT & VON REIS 1956) Increased intracranial pressure may therefore be eliminated as a reasonable cause of the narrowing of the intracranial arteries

The basal cisterns may be transformed into a closed space by meningeal adhesions a condition that constitutes a prerequisite for a local increase in pressure The posterior displacement of the basilar artery in Case 1 indicates that the tuberculous process may act as an expanding lesion The narrowed carotid arteries in Cases 1 and 3 were not displaced but concentrically constricted If such a constriction is due to a locally increased pressure it must be uniformly exerted around the vessel which is a possible mechanism in a closed fluid containing space however the tension within this space must exceed the diastolic arterial blood pressure to compress the arteries and this does not seem very likely to occur A rise in pressure above the systolic blood pressure should completely compress the vessels

The eliciting factor in cerebral vasospasm is not known The fact that all main basal cerebral arteries are not constricted does not exclude spasm as a causative factor as spastic contractions are seen in small and circumscribed

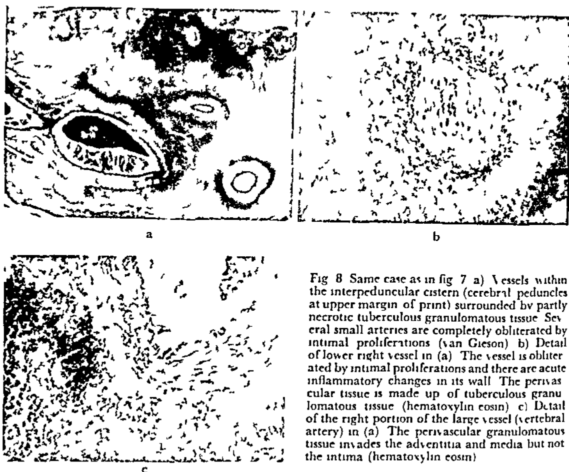


Fig 8 Same case as in fig 7 a) Vessels within the interpeduncular cistern (cerebral peduncles at upper margin of print) surrounded by partly necrotic tuberculous granulomatous tissue Several small arteries are completely obliterated by intimal proliferations (van Gieson) b) Detail of lower right vessel in (a) The vessel is obliterated by intimal proliferations and there are acute inflammatory changes in its wall The perivascular tissue is made up of tuberculous granulomatous tissue (hematoxylin eosin) c) Detail of the right portion of the large vessel (vertebral artery) in (a) The perivascular granulomatous tissue invades the adventitia and media but not the intima (hematoxylin eosin)

areas also in subarachnoidal haemorrhage The minute irregular narrowing of the middle cerebral artery in Case 2 could be due to atherosclerotic changes — although the patient was only 35 — but a slight spastic contraction cannot be excluded The appearances of the vessels in Cases 1 and 3 more closely resemble that of arterial spasm However, in marked spastic narrowing of the carotid siphon a conical area that is not as contracted as the surrounding vessels (Fig 6) is usually left at the junction between the siphon and the anterior and middle cerebral arteries This junction in Case 3 was as narrow and thread like as the remainder of the siphon Vasospasm must be considered as possible but not a very plausible cause of vasoconstriction in tuberculous meningitis

The infectious process in tuberculous meningitis surrounds the basal arteries of the brain and spreads over the convexity along the vessels and invades their walls It is recognized by pathologists that tuberculous vasculitis is a frequent complication and one that may lead to thrombosis and formation of infarcts in the cerebral substance If the infectious process involves the intima there will be a narrowing of the lumen, either due to granuloma formation or diffuse swelling Vessels with considerable intimal thickening may be closely adjacent

to others with no invasion of the intima, as in Case 4 The fact that the constric tive changes are limited to certain areas of the basal arteries is therefore not against vasculitis As a matter of fact nothing contradicts the hypothesis that inflammatory changes in the vessel walls were the cause of all the constrictions seen in the cerebral arteries in this material Vasculitis may of course be com bined with vasospasm but the assumption of such a combination is not neces- sary to explain the changes evident at cerebral angiography

The localized widening of the arteries on the convexity present in Case 4 was not very marked The reason for this dilatation is obscure It could be due to vascular paralysis caused by the infection, which at autopsy was shown to have spread to the convexity Its roentgenologic appearance makes it unlikely that the cause could be an aneurysmal widening a change that occurs in tubercu lous vasculitis

Acknowledgement

The microscopic examinations were performed by Prof C M Fajers whose help is grate fully acknowledged

SUMMARY

Four cases of tuberculous meningitis were examined by cerebral angiography and three had more or less marked narrowing of the arteries at the base of the brain It is suggested that tuber culous vasculitis which may be combined with vasospasm is a plausible explanation for the vascular alterations seen in cerebral angiography

ZUSAMMENFASSUNG

Vier Falle von tuberkulosen Meningitis wurden mittels cerebraler Angiographie untersucht, drei Falle zeigten mehr oder weniger ausgepragte Verengung der Arterien der Schadelbasis Es wird angenommen dass eine tuberkulöse Angitis moglicherweise vergesellschaftet mit Ge fass Spasmus die Ursache der im Angiogramm sichtbaren Veranderungen ist

RÉSUMÉ

Quatre cas de méningite tuberculeuse ont été examinés par angiographie cérébrale trois présentaient une sténose plus ou moins marquée des artères de la base du cerveau L auteur pense que l artérite tuberculeuse qui peut être associée à un spasme vasculaire est une expli cation plausible des altérations vasculaires montrées par l angiographie cerébrale

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR Á KOVÁCS), SEMMELWEIS HOSPITAL, BUDAPEST HUNGARY

ROENTGENOLOGIC EXAMINATION OF THE ARYTENOID CARTILAGE AND VENTRICLE OF MORGAGNI IN THE FUNCTIONING LARYNX

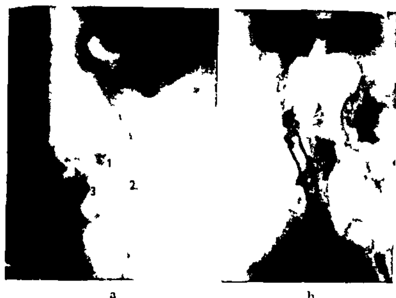
by

ÁKOS KOVÁCS

The arytenoid cartilage may under certain conditions be examined roentgenologically as previously reported (KOVÁCS 1960) Attempts were made in the present study to analyse the movements of the arytenoid cartilage on one hand and the vocal chord and the laryngeal ventricle on the other their actions being closely integrated The arytenoid cartilage lies at the upper margin of the cricoid cartilage and is roughly pyramidal in shape A projection called the muscular process slants backwards and laterally, while a similar eminence, the vocal process is directed forwards the pars intercartilaginea of the glottis lies close to the medial face of the latter The arytenoid cartilage consists of elastic cartilage its ossification begins between the ages of twenty and thirty the first nucleus usually appearing in the central area not infrequently the ossification of the arytenoid cartilage precedes that of the thyroid cartilage

Movements of the arytenoid cartilage may easily be observed at laryngoscopy Alterations in the form and position of the pars intercartilaginea of the glottis the cuneiform cartilage and the cartilage of Santorini, may also be examined by adduction and abduction

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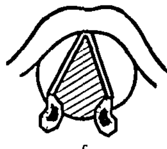


Fig 1 a) Larynx lateral on inspiration Posterior contours of thyroid and cricoid cartilages lie in same vertical plane and the distances between the ossification centres of the arytenoid and thyroid cartilages reach 1 mm ventricle of Morgagni moderately dilated b) P a on inspiration The arytenoid cartilage is foreshortened and the pyriform sinus is dilated c) Horizontal section of the larynx during inspiration

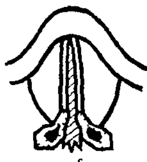
If the arytenoid cartilage is partly or totally ossified, its movement may be detected by lateral fluoroscopy or serial roentgenography Since the change in position is merely a few millimeters, it seems to be satisfactory if only the anterior and posterior extremes of position are recorded in the lateral roentgenogram, the former are attained by high tone phonation and the latter by inflation of the larynx For high tone phonation the vocal chord has to be tightened, which is accomplished by three mechnisms (1) as a result of the action of the crico thyroid muscle, the anterior portions of the thyriod and cricoid cartilages approximate, thus, the arytenoid cartilage carried by the cricoid cartilage moves backwards, acting as a shorter arm of a lever, (2) the arytenoid cartilage is tilted backwards by the action of the arytenoid muscle, (3) the cricoid cartilage also moves backwards in relation to the thyroid cartilage

The following three types of roentgenograms are required for an analysis of the above movements

I The ossified part of the arytenoid cartilage adjacent to the articular surface may be observed as a rhomboidal formation, pushed backwards to the maximum in roentgenograms obtained during high tone phonation (Fig 3a) The



Fig 2 a) Larynx lateral on deep tone phonation Vestibule and hypopharynx dilated posterior contours of thyroid and cricoid cartilages are already in different vertical planes the cricoid cartilage being pushed backwards distance between the ossification nuclei 3 mm ventricle of Morgagni maximally dilated b) P a thick vocal chord and thin membranous false chord the arytenoid cartilage turns inwards its projection being elongated c) Horizontal section



distance between the ossified nucleus of the arytenoid cartilage and the anterior commissure proved to be 17 mm during phonation

II A roentgenogram of the inflated larynx should be obtained to ascertain the dilating capacity (functional capacity) of the larynx The patient should be encouraged to inflate the larynx by *closing* the lips and nose the glottis and hypopharynx are then fully widened the arytenoid and cricoid cartilages being pushed fully forwards by the dilated hypopharynx (Fig 3b) This maneuver, called the inflation of the larynx should be distinguished from the Valsalva maneuver in which the glottis is closed and although the hypopharynx and piriform sinus are moderately widened the arytenoid and cricoid cartilages are pushed forwards to a lesser degree

III The arytenoid cartilage is tilted forwards even if to a lesser degree during deep tone phonation (Fig 2) Although the two arytenoid cartilages do not separate they slide and tilt forwards the vocal chords are thus shortened according to the actual requirements of phonation

The relation of the arytenoid to the thyroid cartilage may also be controlled by this method. The right thyroid lamina in one of the cases of the present material contained an ossification centre, about 2 mm in diameter, which allowed the displacement of the thyroid cartilage to be ascertained. Displacement is observed first of all during high tone phonation, the arytenoid and cricoid cartilages slide backwards and the entire larynx is elevated. The distance between the arytenoid cartilage and the thyroid ossification centre is thus greater than that observed in expiration and inspiration. This distance reached 4 mm in high tone phonation, and only 1 mm in inspiration in one of the cases. The distance proved to be less in deep tone phonation, at least in the inflated larynx, for the arytenoid cartilage with its attaching muscles is then pushed forwards. Valuable data concerning the functional capacity of the larynx and the dilating capacity of the laryngeal tissues may thus be obtained if roentgenograms of the inflated larynx are compared with those obtained during high tone phonation. In the above mentioned case the gap between the posterior margin of the arytenoid cartilage and the anterior commissure was 16 mm in the inflated larynx and 22 mm during high tone phonation, the difference thus reached 6 mm.

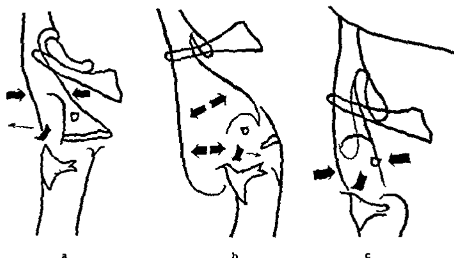
The arytenoid cartilage may be recorded on an asymetrically placed film, as reported in a previous paper (KOVÁCS 1960). The vocal chords and the arytenoid cartilage are seen during inspiration and phonation, superimposed upon each other by a common projection, in Fig. 1, a and b. It may be observed by this method that the vocal process of the arytenoid cartilage is not only pushed medially by phonation but also undergoes torsion, the consequence of which becomes apparent in a flattening of the superimposition.

Opinions on the function of the laryngeal ventricles (ventricle of Morgagni) appear to differ. Most investigators of the physiologic function of the larynx (PRISSMAN & KELEMEN, NEGUS) discuss only a secretory function, which is considered to play an important role in the lubrication of the vocal chord. According to LANZ & WACHSMUTH the walls of the ventricle of Morgagni under normal conditions touch each other. POIRIER CHARPY found that on inspiration the free margin of the false chord was streched and the walls of the ventricle collapsed. More recently, it was established from laryngeal tomograms that during phonation the ventricle of Morgagni contains air.

According to the present results the laryngeal ventricle contains air both during inspiration and phonation, the air content varying according to the tension of the vocal chords. If inspiration is performed, the ventricle is moderately dilated (Fig. 1). It is considerably dilated, and the aperture is also broadly opened, during deep tone phonation (Fig. 2).

The ventricle is, however, flattened and elongated during high tone phonation because the vocal chords are lengthened (Fig. 3a), it is considerably flattened but at the same time shortened in the inflated larynx (Fig. 3b). Performance of the Valsalva maneuver produces complete collapse of the ventricle, and





a b c

Fig 3 a) *Larynx* high tone phonation The vestibule and especially the hypopharynx are narrow posterior lamina of cricoid cartilage tilted 4 mm backwards and downwards and arytenoid cartilage slightly bent backwards ventricle of Morgagni narrow and like the vocal chord considerably elongated b) Inflated larynx Hypopharynx and vestibule fully dilated larynx being pushed forwards Posterior contours of thyroid and cricoid cartilages projected in the same vertical plane arytenoid cartilage being elevated and tilted forwards ossification centres lie above each other ventricle of Morgagni collapsed c) Valsalva maneuver Hypopharynx and vestibule are fully narrowed and the hyoid bone and epiglottis pushed *downwards* no air evident in ventricle of Morgagni

no air can be observed between the approximated walls (Fig 3c) As described in a previous publication (KOVÁCS 1961), the vocal and the false chords come into contact with each other in the Valsalva maneuver and tend to form a common bundle that moves close to the contralateral chords and thus closes the glottis, in the meantime the laryngeal portion of the epiglottic cartilage (paraglottis) assumes a curved contour and bulges backwards to come into contact with the false chords (FINK 1956), pressing all the air out of the ventricle The ventricle usually contains no air in routine roentgenograms of the neck since the exposures are generally made while the patient holds his breath, this maneuver is generally very similar to the Valsalva maneuver

SUMMARY

The roentgenologic demonstration of the shape and position of the arytenoid cartilage and the ventricle of Morgagni was found to be possible in cases in which the centre of ossification of the former was present before calcification of the larynx was complete The method of examination is described and the physiology of the larynx is discussed

ZUSAMMENFASSUNG

Es war möglich, die Form und Lage des Arytenoid Knorpels und des Morgagnischen Ventrikels röntgenologisch darzustellen wenn Ossifikation des ersteren vor der kompletten Verkalkung des gesamten Kehlkopfes eintrat Die angewendete Untersuchungsmethode und die Physiologie des Kehlkopfes werden beschrieben

RÉSUMÉ

Il est possible d étudier radiologiquement la forme et la position du cartilage aryténoide et du ventricule de Morgagni dans les cas ou le centre d ossification du cartilage aryténoide est présent avant que le larynx ne soit complètement calcifié L auteur décrit la méthode d examen et étudie la physiologie du larynx

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FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR TH RASMUSSEN) THE CENTRAL HOSPITAL HJØRRING, DENMARK

CINEMATOGRAPHIC EVALUATION OF GASTROENTEROSTOMY

Preliminary report

by

POVL MADSEN

It has not yet been decided whether emptying of the stomach following gastric resection takes place by active regulation or if this function is mainly passive The radiologic studies and measurements of the intraluminal gastric pressure by JORDAN et coll (1957) appeared to establish that gastric emptying was determined by gravity the tonus of the gastric remnant, movements of the diaphragm and jejunal peristalsis GOODMAN et coll (1958) from their radiologic and gastro electrographic investigations found no significant difference in the gastric emptying time in patients with and without dumping symptoms

PORTER & CLAMAN (1949) concluded from their conventional radiographic studies with barium sulphate that in patients who had been subjected to a Billroth II operation and had a small gastrojejunal stoma the sphincter like effect of the latter was due to contractions of the jejunal muscles CHOCHOLÁC (1960) employing a similar diagnostic technique reported that gastric emptying in Billroth I patients was regulated by a neopylorus which emptied the gastric contents by rhythmic movements into a functioning neobulbus He further observed that gastric emptying in Billroth II patients was regulated by circular contractions in the efferent coil of the anastomosed bowel

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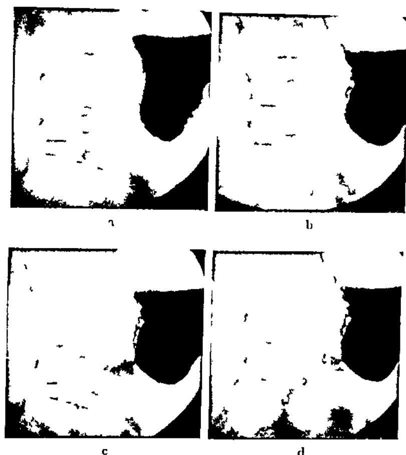


Fig. 1. Normal function of anastomosis following Billroth I resection. a) Phase of spasm. b) incipient and c) maximum filling of the neo-bulbus. d) emptying phase.

Investigations into the gastric emptying rate with physiologic contrast media have lately been carried out by ABBOTT et coll. (1958, 1960), MATTSSON et coll. (1960), and MADSEN & RASMUSSEN (1964). The reason for using physiologic contrast media is based upon the notion that barium sulphate exerts no physiologic action in the gastrointestinal tract and cannot therefore be suitable for giving information regarding function.

ABBOTT considered that the absence of any reservoir function of the gastric remnant, and a rapid passage of the meal through the small intestine, were characteristics of the dumping syndrome. MATTSSON examined 18 patients who had been subjected to subtotal gastrectomy and reported a normal gastric emptying rate despite rapid passage of the meal through the small intestine in 12 of those who had dumping symptoms. MADSEN studied 55 patients who had undergone subtotal or total gastrectomy. The gastric emptying rate and the passage of the meal through the small intestine were on the whole normal in those who had no dumping symptoms. Dumpers usually had a greatly ac-



Fig 2 Normal function of anastomosis following Billroth II resection a) Phase of spasm b) incipient and c) maximum filling of jejunal bulb d) emptying phase

celerated gastric emptying and passage through the small intestine as well as radiologic evidence that fluid oozed into the small intestine The divergent findings in the gastric emptying rate in dumpers may have been due to MATTSSON's demand that the time was not to be recorded before the stomach was completely empty while MADSEN considered the stomach to be empty when a fluid level was no longer visible (quantitative gastric emptying time)

The considerable variations in the quantitative gastric emptying time recorded in patients who had undergone resection appeared to call for a further study of the regulation of the emptying of the gastric remnant

Method The function of the gastroenterostomy was assessed cinematographically following the administration of a physiologic contrast medium made up of Neobar 40 g Redukal Leo 55 g and sucrose 20 g in 200 ml water and emulsified in an electric mixer caloric value about 300

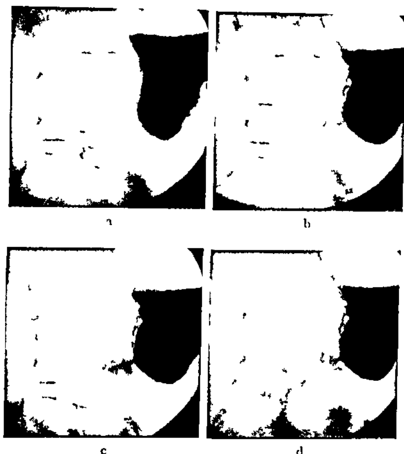


Fig 1 Normal function of anastomosis following Billroth I resection a) Phase of spasm b) incipient and c) maximum filling of the neo bulbus d) emptying phase

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Table 3

Gastric emptying time in the presence of insufficient bulbar function

Case	Operation	Gastric emptying time	Symptoms
16	B I	1—20 min	Latent dumping
17	B I	1—20 min	Latent dumping
18	B I	1—20 min	Manifest dumping
19	Hofmeister	20—45 min	Manifest dumping
20	B I	1—20 min	Latent dumping
21	B I	1—20 min	None
22	Subtotal gastrectomy transposition of jejunum	1—20 min	Latent dumping
23	B II small stoma	1—20 min	Latent dumping
24	B I	1—20 min	Latent dumping

Symptoms of the 'small stomach' type are taken to mean that after small to moderate meals there is a feeling of pressure in the epigastric region and below the left costal margin. Pain and vomiting occurred in severe cases.

Postcibal pressure in the epigastric region and below the right costal margin followed by severe vomiting with bile stained vomitus is designated the afferent loop syndrome. Some authors do not distinguish between the small stomach syndrome and the afferent loop syndrome. ANDREASSEN (1960) considers it a moot point whether there is justification to keep these syndromes distinct from the dumping syndrome.

Results

The structures described by CHOCOLAC were identified in the patients who had undergone the Billroth I operation. With normal function the neopylorus opens for a period of 2 to 4 sec and the neobulbus fills, there is no flow into the duodenum during this filling. Emptying of the neobulbus takes place by its

Table 4

Gastric emptying time in the presence of spasm

Case	Operation	Gastric emptying time	Symptoms
25	B II small stoma	45—90 min	None
26	B I	20—45 min	Small stomach Latent dumping
27	B II small stoma	> 90 min	Small stomach Latent dumping
28	B I	45—90 min	Small stomach Latent dumping
29	Hofmeister	> 90 min	Afferent loop
30	B II small stoma	> 90 min	Small stomach
31	B II small stoma	> 90 min	Small stomach
32	B II small stoma	> 90 min	Small stomach

Table 1

Gastric emptying time with normal function of anastomosis

Case	Operation	Gastric emptying time	Symptoms
1	B II small stoma	> 90 min	None
2	B II small stoma	> 90 min	None
3	B I	45—90 min	None
4	Polya	> 90 min	Afferent loop
5	B II small stoma	> 90 min	None
6	B I vagotomy	> 90 min	None
7	B II small stoma	45—90 min	None
8	B I	> 90 min	None
9	B I	45—90 min	Latent dumping
10	Hofmeister	> 90 min	Afferent loop malabsorption
11	B II small stoma	> 90 min	Small stomach or afferent loop (?)
12	B I	45—90 min	None
13	B I	> 90 min	None

The examination was carried out with a 9 Philips image amplifier mounted on a Muller table, type UG 4, a 35 mm Arriflex camera and television monitor being coupled to the former. Exposures were made at intervals of 15 sec and started less than 5 min after the ingestion of the contrast medium. The film rate was 12 or 16 exposures per second, 25 metres of film were used for each examination.

Prior to the cinematographic study the gastric emptying and small intestine transit times, as well as the amount of oozing of fluid into the small intestine, had been evaluated following the administration of the same amount of physiologic contrast medium used for the main study. Views of the abdomen 'erect' were obtained on 30 × 40 cm films at 1, 20, 45, and 90 min after the ingestion, in between the exposures the patients sat or walked about.

Material. The material comprises 32 patients who had undergone gastric operations, 14 by the Billroth I and 17 by the Billroth II procedure. Subtotal gastrectomy with jejunal transposition had been performed in one patient.

The dumping symptoms were classified into latent and manifest from the diet history. Patients with latent dumping can avoid symptoms by dietary precautions, while manifest dumpers have frequent or constant symptoms despite dietary precautions.

Table 2

Gastric emptying time in the presence of passive anastomotic function

Case	Operation	Gastric emptying time	Symptoms
14	B II small stoma	20—45 min	None
15	Hofmeister	45—90 min	None



Fig 5 Afferent loop syndrome and malabsorption 1 20 45 and 90 min p c Large intermediate layer in gastric remnant at 90 min p c no filling of afferent loop spontaneous fractures through the inferior ramus of the right pubic bone and neck of the left femur noted.

rate of gastric emptying (Table 3) The same must apply when the anastomosis is passive (Table 2) Emptying has been found to be accelerated during inspiration provided that the anastomosis is passive or the bulbar function insufficient The relation between the duration and intensity of spasm and the tonus of the gastric wall must decide the rate of gastric emptying when the anastomosis is spastic (Table 4) Antiperistalsis in the duodenum of Billroth I patients and in the efferent loop of Billroth II patients has occasionally been found to cause retrograde filling of the stomach remnant and thereby delay its emptying

Discussion

Nine patients had dumping symptoms (Cases 9 16 17 18 19 20 22 23, and 24) which were severe in two (Cases 18 and 19) Typical dumping symptoms occurred during the examination in 6 of these patients One patient had normal gastroenterostomy function Bulbar function was insufficient in the others The gastric remnant emptied rapidly the passage through the small intestine was accelerated and there was evidence of oozing of fluid *into the* small intestine (Fig 3) The rapid gastric emptying per se can hardly be the cause of dumping but it may well influence the intensity of the symptoms in the presence of a predisposition to this phenomenon This assumption is supported by the favourable effect of operation performed to narrow *the stoma* (ABBOTT et coll 1958 1960 AMDRUP 1960)

Six patients had symptoms of the small stomach type (Cases 26 27 28 30 31 and 32) *and 3 also had* dumping symptoms The small stomach symptoms in one patient were considered severe (Case 30) and the patient complained of pain *in the* epigastric region and below the left costal margin during the examination The gastric *remnant* was spherical in the erect films as well as on fluoroscopy and all the patients had evidence of spasm at the stoma (Fig 4)



Fig 3 Dumping syndrome 1 20 45 and 90 min p c respectively from left to right The gastric remnant empties rapidly the transit through the small intestine is accelerated and there is evidence of *oozing of fluid into the small intestine at 1 and 20 min p c*

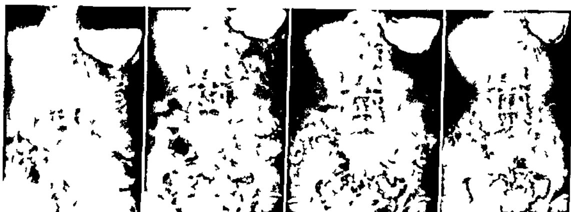


Fig 4 Small stomach syndrome 1 20 45 and 90 min p c Spherical gastric remnant flow into the small intestine followed by a prolonged spasm of the stoma occurring immediately after ingestion of the contrast medium

circular contraction and takes 2 to 4 sec, when the neobulbus is empty there *follows a phase of less than 30 sec duration during which the neobulbus* and neopylorus are contracted The filling of the neobulbus then starts anew (Fig 1)

It is seldom possible to identify a neopylorus with certainty in Billroth II patients Emptying is regulated by the first 3 to 5 cm of the efferent loop called the 'jejunal bulb The phase of filling lasts for 2 to 4 sec and the phase of emptying is of the same duration After the jejunal bulb has emptied, a phase of contraction, lasting for less than 30 sec, occurs (Fig 2)

The following types of abnormal function have been observed (1) insufficient bulbar function, the emptying phase starting before the filling phase has been completed with the spasm phase shortened, (2) passive anastomotic function, (3) anastomotic spasm

It appears from Table 1 that normal anastomosis function is associated with the slowest gastric emptying Gastric emptying is accelerated in the presence of insufficient bulbar function, and peristalsis in the small intestine controls the

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One patient with similar signs was symptom free It was impossible to decide whether the symptoms were attributable to a small stomach or an afferent loop syndrome in one instance (Case 11) The film 90 min p c revealed an intermediate layer and contrast medium in the spherical gastric remnant despite severe vomiting of bile stained fluid in the middle of the examination, the stoma function was normal

Three patients had afferent loop symtoms (Cases 4, 10 and 29) associated in one with a marked malabsorption syndrome (Fig 5) Films 45 and 90 min p c revealed an increasing intermediate layer in the gastric remnant and the gastric contents 90 min p c were at least as large as at 1 min p c It was reported in a previous study that a physiologic contrast medium has a slight tendency to sedimentation despite the addition of gastric juice (MADSEN & RASMUSSEN 1964) The intermediate layer might therefore be expected to contain considerable quantities of bile and pancreatic juice, and laboratory analyses performed in three patients confirmed this assumption Two of the patients had normal function while the third had spasm at the stoma, there was no filling of the afferent loop

Conclusion

A postcibal syndrome in patients who have undergone gastric surgery may be correlated with characteristic roentgen appearances if a physiologic contrast medium is employed A final elucidation of the value of this method probably requires a larger series

Cinematographic studies of the reaction of a gastroenterostomy to a physiologic contrast medium may elucidate the abnormalities of function that may arise in the gastrointestinal tract

SUMMARY

Cinematographic studies of function with a physiologic contrast medium were performed in 32 patients who had undergone gastroenterostomy The dumping syndrome is discussed with reference to characteristic appearances

ZUSAMMENFASSUNG

Kinematographische Untersuchung mit einem physiologischen Kontrastmittel wurde an 32 Patienten vorgenommen die eine Gastroenterostomie hatten Das dumping Symptom und seine charakteristischen Rontgenerscheinungen werden besprochen

RÉSUMÉ

L auteur a fait sur 32 malades gastro entérostomisés une étude cinématographique de la fonction avec un moyen de contraste physiologique Il examine les images caractéristiques du dumping syndrome

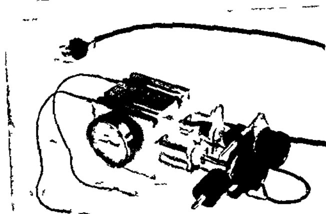


Fig 1 Lymphangiography injector pump

via the kidneys and bile It does not bind with blood protein as is the case with methylene blue and its biological half life is measured in hours compared to weeks for methylene blue and sky blue (THREEFOOT 1960) Thus, it does not result in cosmetic tattoo at the injection site

2 *Catheters* After trying several home made and commercially available lymphangiography catheters we believe that the simplest is the one made by Beckton Dickinson Co (Rutherford N J U S A) it is a large bore 20 long polyvinyl catheter serial number V15504 Attached to the catheter we use Beckton Dickinson needles 3/4 long 27G or 30G

3 *Lymphangiography injector pump* We have used oily contrast material in almost all our studies The speed of the injection can be increased by the use of large bore catheters and of an automatic temperature control injector where the contrast material is heated and kept warm at constant temperature (Fig 1) Our injector permits simultaneous independent injection into each extremity of the contrast material in two 20 ml syringes Our unit will inject at a maximum of 0 5 ml per minute The solution is temperature controlled by a thermostat knob Heating of the oily contrast material at approximately 80 C will determine that the oil at the tip of the needle will have a temperature of 37 5 C with the length and type of catheters that we use The injector s mechanical electrical mechanism is torque controlled and injection rates are pressure compensated to each syringe independently This mechanism gives a wider latitude of rate/pressure control with near perfect reliability under the command of the operator

FROM THE DEPARTMENT OF RADIOLOGY, SCHOOL OF MEDICINE, UNIVERSITY OF MIAMI, JACKSON MEMORIAL HOSPITAL, U S A

ADVANCES IN LYMPHANGIO-ADENOGRAPHY

by

M VIAMONTE Jr

Since June 1960 and up to the time of publication, we have performed 404 successful lymphangio adenographic studies, and the purpose of this paper is to present new developments in our technique We have used a technique which is essentially the same as the one introduced by KINMONTH (1952) but with the modifications exposed in the following

1 Blue dye Instead of patent blue V we have been using FDC blue No 1, which is a synthetic dye approved by the US Government for use in foods, drugs and cosmetics

Brilliant blue FCF, which is officially designated as FDC blue No 1, has been investigated and found to be safe for use as a coloring agent in foods drugs and cosmetics, but it has not been approved by the US Food and Drug Administration for human use by parenteral administration Because chemically it is related to alphazurine 2G — purified patent blue V — we have successfully used it in our last 200 cases and it has proved to be non toxic and with similar staining characteristics for identification of lymphatics

The maximum dose we have used intradermally has been 2 ml of a 10 % solution by weight This dye is superior to methylene blue or sky blue, because it is rapidly absorbed from the injection site and rapidly excreted from the body

Submitted for publication 9 January 1963



Fig 3 Roentgenograms of the injection site showing from left to right local extravasation lymphatic injection and inadvertent venous injection (some lymphatics are also demonstrated)

4 Radiographic monitoring of injections All of our lymphangio adenographic studies are performed in the radiology department After injecting the first 2 ml fluoroscopy or a roentgenogram is obtained of the extremity to confirm the intralymphatic position of the needle We have found that the ideal device for observing the injection is fluoroscopic intensification with television presentation since this allows direct observation of the injection in the extremity without delay and without dark adaptation of reduced illumination in the injection area (Fig 2) This will rule out local extravasation and inadvertent venous injection (Fig 3)

After half of the total amount has been injected fluoroscopy or a roentgenogram of the pelvis is obtained to determine if there is any obstruction to the lymph flow If there is any evidence of obstruction the injection is discontinued When obstruction to the lymph flow is present the contrast medium rapidly penetrates the venous circulation Pulmonary oil embolism with complicating chemical bronchopneumonia may then occur

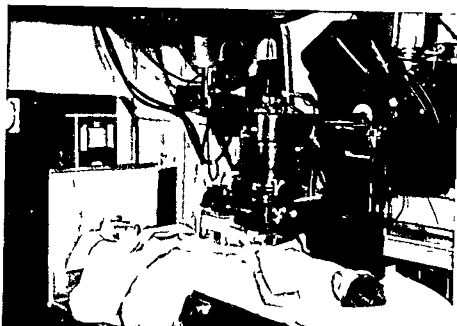


Fig 2 Biplane cine angiographic unit with television monitor

Each motorized syringe forcing unit is driven by an aluminum finger, riding on a pressure sensitive aluminum knurled nut which in turn is driven by a rotating brass lead thrust screw, ball bearing mounted. Adjustment of a counter torque weight on each injector determines the injection rate. The injection rate can be increased beyond the maximal power driven rates by manually turning the drive nut clockwise, while power is on or off the drive motors. Our injector will maintain fluid temperature and by means of separate and independent controls, it will check the fluid injection rate of two 20 ml syringes simultaneously.

The back of the injector is slightly elevated and a bubble of air is placed in each syringe. This bubble of air is heated and at the same time compressed during the injection. When the intralymphatic pressure equalizes the pressure of injection, the motor automatically shuts off. The air bubble then tends to expand and in this way permits a continuous flow of the contrast material, in spite of the intermittent function of the motors.

We have been able to cut the time of injection with our injector to 30 to 45 minutes as an average (12 to 15 ml in 30 minutes). The pressure of the injection is determined by the amount of leakage at the injection site, the pain that the patient may experience, and by the presence of extravasation of contrast material in the course of the lymphatics or at the level of the inguinal nodes. We have been able to eliminate the pain that is occasionally referred in the calf region by the initial injection of 2 or 3 ml of 2 % xylocaine[1] (lydocaine) followed by the injection of the contrast material.



Fig 5 Radical adenectomy with the aid of chromolymphography

of the green lymph channels and the green lymph nodes Adenectomy should be performed within 24 to 48 hours after the injection of contrast material After the second day the green tends to fade out due to the diffusion of the chlorophyll

We have confirmed the value of chromolymphography for demonstrating that a more complete adenectomy has been performed, as compared to the cases in which the green contrast material has not been used (Figs 4 and 5) Roentgenograms obtained in the operating room serve as controls of the extension of adenectomy

6 *Indirect lymphangio adenography* In order to facilitate and expand the field of lymphangio-adenography we are experimenting with different radioopaque macromolecules (in studies supported by NIH grant CA 06567 01) Our preliminary studies have shown that it is possible to demonstrate the lymphatic system of an extremity in the dog by the interstitial injection of contrast material This has been shown in the past by different authors that have used such contrast materials as Thorotrast (ARNULF 1958) Hypaque (DANESE et coll 1962) Unfortunately lymphatic absorption characteristics in the animal are not equivalent to those in man and the results of animal experiments cannot yet be transposed to the human The future clinical usefulness of lympangio adenography will depend on the discovery of the type of molecule which may permit the demonstration of the lymphatic system in many territories of the human body which cannot at present be demonstrated by the direct lymphatic injection method



Fig 4 Inadequate adenectomy residual nodes

After the completion of the injection (when 15 ml have been injected in each lower extremity smaller amount in infants and children) the patient is fluoroscoped or roentgenograms of the abdomen and chest are obtained As soon as the thoracic duct is visible, the injection is discontinued Over injection of *contrast material, especially in infants, also favors the production of pulmonary* oil embolism We have had this complication in 15 patients Roentgenograms of the pelvis and abdomen are always obtained at the completion of the procedure and 24 or 48 hours later We always take frontal, lateral, and oblique views, and occasionally tomograms in order to evaluate the nodal architecture in detail

5 *Chromolymphography* For the last two and a half years we have been using green ethiodol in pre adenectomy patients After experimenting in animals with different colored contrast materials, as well as with fluorescent and with radioactive media, we concluded that a dark green ethiodol which is obtained by the mixture of plain ethiodol and 5 % chlorophyll, would be most useful This contrast material is as safe as the plain ethiodol and stains the lymphatics in pale green The use of green ethiodol, more than fluorescent or radioactive material, facilitates pelvic or abdominal adenectomy by the easy identification



Fig 5 Radical adenectomy with the aid of chromolymphography

of the green lymph channels and the green lymph nodes Adenectomy should be performed within 24 to 48 hours after the injection of contrast material After the second day, the green tends to fade out due to the diffusion of the chlorophyll

We have confirmed the value of chromolymphography for demonstrating that a more complete adenectomy has been performed as compared to the cases in which the green contrast material has not been used (Figs 4 and 5) Roentgenograms obtained in the operating room serve as controls of the extension of adenectomy

6 *Indirect lymphangio adenography* In order to facilitate and expand the field of lymphangio adenography we are experimenting with different radioopaque macromolecules (in studies supported by NIH grant CA 06567 01) Our preliminary studies have shown that it is possible to demonstrate the lymphatic system of an extremity in the dog by the interstitial injection of contrast material This has been shown in the past by different authors that have used such contrast materials as Thorotrast (ARNULF 1958) Hypaque (DANESE et coll 1962) Unfortunately lymphatic absorption characteristics in the animal are not equivalent to those in man and the results of animal experiments cannot yet be transposed to the human The future clinical usefulness of lympangio-adenography will depend on the discovery of the type of molecule which may permit the demonstration of the lymphatic system in many territories of the human body which cannot at present be demonstrated by the direct lymphatic injection method

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We are grateful to Mr C H Bradney from E Fougera & Company for providing FDC blue dye and green ethiodol to Mr C J Hobbs for the development of our lymphangiography injector pump and to Mr Ed May from Beckton Dickinson Company, and to Mr C McCune from Jackson Memorial Hospital for the catheters we have used The author is indebted to Raymond E Parks, M D , for valuable suggestions and for reviewing the manuscript

SUMMARY

Technical difficulties of direct lympangio adenography are minimized with the use of FDC blue dye large bore catheters and an automatic pressure temperature control injector pump Radiologic control at the beginning during and at the end of the procedure decreases the failures and prevents some of the complications Green ethiodol has proved to be a valuable surgical aid for pelvic and periaortic adenectomy Indirect lymphangio adenography has clinical and research potentialities

ZUSAMMENFASSUNG

Die technischen Schwierigkeiten der Lympho Adenographie werden behoben wenn man FDC blau als Farbe und weite Katheter sowie automatische Injektionspumpen die Druck und Temperatur regulieren, benutzt Rontgenologische Kontrolle im Beginn wahrend und nach der Untersuchung vermindert Fehler und vermeidet Komplikationen Grunes Ethiodol hat sich fur die chirurgische Entfernung von Lymphknoten des Beckens und von der Umgebung der Aorta als nutzlich erwiesen Indirekte Lympho Adenographie erbietet Moglichkeiten fur die Klinik und fur die Forschung

RÉSUMÉ

L utilisation du bleu FDC de cathéters à lumière large et d une pompe d injection à régulation automatique de température et de pression diminue les difficultés techniques de la lymphangio adénographie directe Le contrôle radiographique au début pendant et à la fin de l injection rend les échecs moins fréquents et évite certaines complications L ethiodol vert facilite l adénectomie pelvienne et périaortique La lymphangio adénographie indirecte fournira de nouvelles possibilités à la clinique et à la recherche

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PHYSICO CHEMICAL PROPERTIES OF BLOOD FOLLOWING EXPOSURE TO METHYLGLUCAMINE IODIPAMIDE, AND OTHER CONTRAST MEDIA

by

EUGENE F BERNSTEIN ROBERT L EVANS and GEORG FREDRIK SALTZMAN

During the last decade, a number of angiographic contrast media with very low toxicity have been developed However, iodipamide (Biligrafin Cholografin) the only parenteral contrast medium for biliary tract examinations remains as a problem in toxicity. The toxic actions of iodipamide are similar both in kind and in degree to those caused by the acetrizoate (Urokon Triurol) media The more common side effects include nausea, headache urticaria and diarrhea More severe complications including circulatory collapse and hemiplegia are rare, but have been reported (HORNYKIEWYTSCH 1956 SALTZMAN 1959 SALTZMAN & SUNDSTROM 1960) Both in experimental (LINDGREN & SALTZMAN) and clinical (SALTZMAN & SUNDSTROM) studies the injection of iodipamide is routinely followed by a period of hypotension Furthermore a number of deaths have been described following iodipamide injection (FROMMHOLD & BRABAND MAURER)

Recently attention has been focused upon the phenomenon of intravascular aggregation of red-blood cells as an important factor in angiographic contrast

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media toxicity (READ, SOBIN et coll., BERNSTEIN & EVANS). *Intravital microscopy* (LINDGREN et coll.) has also revealed the frequent development of increased intravascular aggregation following the injection of iodipamide. Increases in pulmonary artery pressure, which are avoided by pretreatment with low molecular weight dextran, have been observed by the same investigators, in a similar manner to that demonstrated for the diatrizoate compounds by BERNSTEIN & EVANS.

Recent studies by CHAPLIN & CARLSSON, using high concentrations of various angiographic contrast media, but not iodipamide, have demonstrated important effects upon various physico-chemical properties of blood. These authors state that contrast media are able to affect red blood cells directly, causing hemolysis, but they were unable to find evidence of significant red blood cell aggregation.

Several other recent papers have discussed the role of the plasma proteins in the toxicity of parenteral contrast media. LASSER et coll. state that protein binding is of considerable importance in such toxic reactions, that this binding is a specific one between the contrast media and albumin, and that the degree of toxicity of contrast media is directly proportional to their ability to bind albumin. KUTT & McDOWELL studied the proteins in human serum, both in vitro and in vivo, following exposure to contrast media of the diatrizoate type. They noted an increase in the gamma globulin fraction, and a decrease in albumin, which they also felt were related to toxicity. In addition, they emphasized the clinical observation of some deaths following intravenous urography in patients with myeloma, in whom the gamma globulin fraction was markedly increased prior to the injection of a radiopaque medium. On the other hand, LEOPOLD & HEUCK demonstrated changes in the protein spectrum in their studies but did not feel that these changes played an important role in the toxic process.

Intravascular aggregation has been associated with an increased sedimentation rate in the classical descriptions by FAHRAEUS, and many later investigators. On the other hand, ROPES et coll. felt that variations in the sedimentation rate were due to variations in the colloidal state of the plasma, and were a result of changes in electric charges on the proteins and red blood cells. LINDGREN et coll. studied the sedimentation rate following in vitro mixtures and clinical injections of iodipamide, and were surprised to note a remarkably diminished sedimentation rate in both of these circumstances.

All of these observations stimulated us to study some of the physico-chemical properties of blood following exposure to iodipamide, and some other parenteral contrast media. It was hoped that these studies would provide some additional information concerning the mechanism of iodipamide toxicity.

Initially, we planned to partition the sedimentation rate into the factors which have been considered important in determining the rate at which particles will fall when suspended in a viscous medium. According to Stokes' law, the three determining factors should be (1) the radius of the falling particle (RBC), (2) the difference in density between the falling particle and the suspending

Table 1

Radiopaques used in detailed studies

Preparation	Amount in ml added to 30 ml whole blood	Final concentration mg
1 Cholografin (Squibb) 52 %	0 075	0 13
2 Cholografin (Squibb) 52 %	0 5	0 86
3 Hypaque (Winthrop) 50	0 075	0 13
4 Hypaque (Winthrop) 50 %	0 5	0 84
5 Hypaque (Winthrop) 90	0 075	0.23
6 Hypaque (Winthrop) 90	0 5	1 50
7 Cholografin (Squibb) 52	injected into dog in dose of 0 5 ml/kg body weight	

medium (plasma) and (3) the viscosity of the suspending medium Experiments were planned to measure these properties both following in vitro mixing of known concentrations of contrast media and blood and following the in vivo injection of iodipamide In addition to iodipamide (in our experiments 52 % methylglucamine Cholografin) Hypaque 50 % and 90 % (a diatrizoate medium) was chosen for comparative observations

Early observations of the factors just described suggested the following additional measurements also to be performed whole blood viscosity, hematocrit plasma hemoglobin red blood cell charge and serum electrophoresis

Methods

A *Experimental preparation* Mongrel dogs of both sexes were anesthetized with 30 mg/kg sodium pentobarbital and a polythene catheter was inserted into one femoral artery Blood for serum electrophoresis was collected in 3 tubes before heparinization one of the tubes was for control and the two other tubes contained Cholografin and Hypaque respectively corresponding to concentrations of 0 86 mg and 1 50 mg % Heparin was then given in a dose of 6 mg/kg body weight and the dog bled approximately 300 ml This blood was gently mixed in a beaker and divided into in vitro dilution samples The dilution samples contained the concentrations of contrast media indicated in Table 1 The dilute in vitro concentrations were calculated to equal the clinical doses used in routine intravenous urography and cholangiography The concentrated solutions were prepared to determine the additional effects of higher doses of these media Plasma for all the analyses was collected after centrifugation for 15 minutes at 2 500 rpm Following the removal of blood for in vitro studies an intravenous injection of 0 5 ml kg of Cholografin 52 — a dose designed to equal the largest clinical dose generally employed in human medicine — was made Three minutes later an additional sample of arterial blood was obtained All the blood samples were analyzed for sedimentation rate hematocrit plasma and whole blood viscosity plasma and red blood cell density plasma hemoglobin red blood cell density, red blood cell charge and serum electrophoresis

B *Analytical techniques* Erythrocyte sedimentation rate was measured by observing settling in Westergren tubes for 60 minutes

Hematocrit was determined by centrifuging Wintrobe tubes for thirty and sixty minutes at 2 500 rpm

Whole blood and plasma viscosity were measured using a modified ECKSTEIN BOOK & GREGG viscometer of the capillary tube type in comparison with the viscosity of distilled water at

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Table 2

One hour sedimentation rates in 13 experiments

Experiment	Control	Cholografin in vivo 0 5 ml/kg body weight	Cholografin in vitro (0 13 mg %)	Cholografin in vitro (0 86 mg %)
1	50	32	32	0
2	4	0	1	0
3	21	1	6	0
4	14	1	1	0
5	2 5	0 5	1	0
6	6	1	2	0
7	58	2	15	0
8	13	0	3	0
9	2	0	0	0
10	11	2	3	0
11	49	15	49	0
12	9	0	0 5	0
13	3	0	0	0

20 C All samples were studied at room temperature which was within one degree of 24 C Plasma density was measured by weighing 5 ml in pycnometer containers

Red blood cell density was initially obtained with the same pycnometer technique using the red blood cell fraction of a blood specimen centrifuged at 2 500 rpm for 15 minutes Because of the difficulty in obtaining tightly packed RBC fractions in some of the samples and because of the difficulty in transferring such fractions an additional approach was employed The alternate technique involves obtaining the whole blood density with pycnometers and calculating the red blood cell density from the plasma density 60 minute hematocrit and the formula $\varrho_{bl} = \varrho_{RBC} \frac{h}{100} + \varrho_{pl} \frac{(100 - h)}{100}$ where ϱ is density (gm/cm^3), h is hematocrit bl equals whole blood RBC is the red blood cell fraction and pl means plasma

Plasma hemoglobin was determined with the technique of FLINK & WATSON

Red blood cell diameters were measured directly by examining a drop of plasma with some suspended red blood cells on a glass slide using 980 magnifications and a calibrated eyepiece micrometer disc

Red blood cell charge was determined utilizing a modification of the Abramson micro electrophoresis apparatus re suspending some red blood cells in their own plasma following initial centrifugation

Serum paper electrophoresis was performed using the Spinco Paper Electrophoresis apparatus Model R Durram Type with Spinco Duostat Power Supply with a Spinco Analytrol Model RA

C *Mathematical methods* One can attribute a certain viscosity contribution to the red cells contained in a suspension such as blood if it is assumed that the cells and the liquid contribute linearly according to the proportions in which they are present This amounts to defining a red blood cell viscosity by the equation

$$\eta_{bl} = \frac{h}{100}\eta_{RBC} + \frac{100-h}{100}\eta_{pl} \text{ or } \eta_{RBC} = \frac{100\eta_{bl} - (100-h)\eta_{pl}}{h}$$

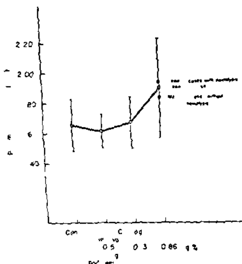


Fig 1 Plasma viscosity after exposure to Chólografin Averages and S D s in 13 experiments

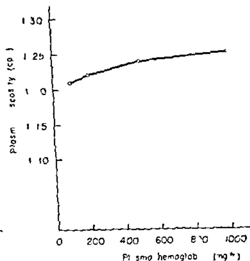


Fig 2 Relationship between plasma viscosity and plasma hemoglobin Mean of 3 experiments

where h is the hematocrit η_{bl} is the viscosity of the whole blood and η_{pl} is the viscosity of the plasma This definition of red blood cell viscosity has been used previously by BERNSTEIN et coll

It is possible to calculate Fåhraeus equivalent radius of a particle (or aggregation of particles) by equating the two forces that oppose each other during sedimentation at a steady rate Fåhraeus called these forces the active gravity and the Stokes resistance and he expressed them as $4/3\ \pi r^3\ (s-s_1)\ g$ and $6\pi\ r\ v\ \eta$ respectively where r is the equivalent radius (in cm) $(s-s_1)$ is the excess of particle density over liquid density (in g/cm³) g is the gravitational constant (980 6 cm/sec²) v is the particle velocity (cm/sec) and η is the liquid viscosity (poise) On equating these forces and solving for the equivalent radius or Stokes radius one finds that

$$r = \sqrt{9/2\ v\ \eta / g\ (s-s_1)}$$

Results

A *Chólografin*

1 *Sedimentation rate* Results of sedimentation rate studies both in vitro and in vivo are presented in Table 2 In each of the 13 studies the in vitro samples with 0 86 mg% Chólografin had no observable sedimentation rate In addition, in all of the samples obtained after in vivo injection and in all but one of the 0 13 mg% samples there was a marked reduction in the sedimentation rate These observations confirm those previously made by LINDGREN et coll, and serve as a baseline for further experiments

2 *Viscosities* The mean results (± S D) of 13 observations of *plasma viscosity* are summarized in Fig 1 The 0 86 mg% Chólografin samples contained the highest plasma viscosity in 12 of the 13 experiments in nine the 0 13 mg%

Table 3

Relationship between plasma viscosity and sedimentation rate in 13 control samples

	Experimental groups	
	Low sedimentation rate (8 experiments)	High sedimentation rate (5 experiments)
Range of sedimentation rate	2 5 to 13 mm/hr	14 to 58 mm/hr
Range of plasma viscosity	1 39 to 1 73 cps	1 74 to 1 94 cps

samples had higher viscosity than the controls Included in Fig 1 are also the average values of the experiments with and without hemolysis in the 0 86 mg% Cholografin samples Plasma hemoglobin determinations were carried out in only 8 cases (see Fig 8) In the remaining 5 cases the plasma was hemolyzed but the degree of hemolysis was not known

Hemolysis alone causes a slight increase in plasma viscosity, as shown by observations on plasma (Fig 2) to which various concentrations of hemoglobin solution have been added These changes are, however, not of the same size as those observed after exposure to Cholografin

The plasma viscosity of the in vivo Cholografin samples was lower than the control samples in 10 of the 13 studies This is very difficult to explain It may be mentioned, however, that these samples (after the injection of Cholografin) were obtained from animals that had previously been used as blood donors for the in vitro part of the experiment

The lowest plasma viscosities were seen in the control samples in the eight experiments in which the sedimentation rates were lowest (Table 3)

A consistent increase in *whole blood viscosity* was seen with Cholografin, in proportion to its concentration (Fig 3) There were also increases in whole blood viscosity in each of the in vivo samples, as compared with the controls

Marked increases in the *apparent red blood cell viscosity* were seen with Cholografin both in vivo and in vitro (Fig 4), and these increases corresponded with the concentration of Cholografin

3 *Densities* The changes in *plasma density* (9 observations) in the various samples are depicted in Fig 5 It is seen that the changes are quite small, but the density in the control was always lower than in all the in vitro samples, and lower than those after in vivo injection in 8 out of 9 cases The highest plasma density was always seen with the 0 86 mg% Cholografin samples

The *whole blood density* was measured only for the RBC density calculations and is not of interest in itself

It is obviously very difficult to measure the actual *density of 'dry' red blood cells* One can only measure the density of relatively well packed RBC s Further, a high degree of packing makes it difficult to transfer the RBC s to the pycnometer for weighing For these reasons, two different methods have been used to meas

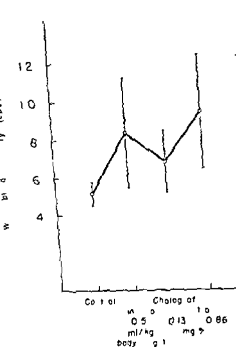


Fig 3 Whole blood viscosity after exposure to Chlolografin Averages and S D s in 6 experiments

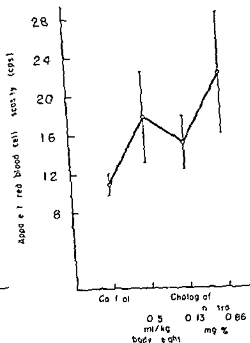


Fig 4 Apparent red blood cell viscosity after exposure to Chlolografin Averages and S D s in 6 experiments

ure RBC density in 6 experiments measurements of whole blood density and calculations of the RBC density from the one hour Hct were performed in another 3 experiments direct measurements of the density of the RBC fractions were performed with pycnometers after 15 minutes of centrifugation at 2 500 rpm The average curves (Fig 6) correspond well in all but one point the 0 86 mg% Cholografin samples In other words when the red blood cells are less well packed the RBC density will appear to be lower in the 0 86 mg% Cholografin than in all other samples including the controls In all instances the densities obtained with the whole blood density and one hour hematocrit data were higher than those obtained with the RBC fraction after 15 minutes of centrifugation This is a result of the additional RBC packing which occurs during the prolonged Hct centrifugation

4 *RBC diameter and shape* The average red blood cell diameters observed are depicted in Fig 7 Following injection of Cholografin there was a decrease in diameter from a control value of approximately 6 9 μ to 5 6 μ With the 0 86 mg % in vitro Cholografin dilution there was a further decrease to the range

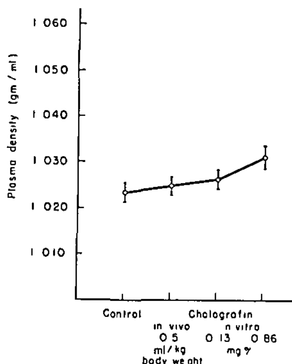


Fig 5 Plasma density after exposure to Cholografin Averages and S D s in 9 experiments

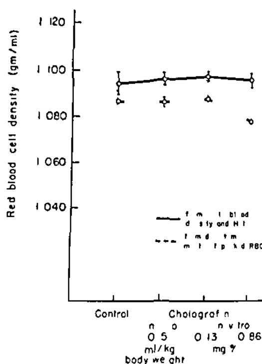


Fig 6 Red blood cell density calculated from whole blood density plasma density and one hour hematocrit (6 experiments) and directly measured (3 experiments) Average values and ± S D s

of 5 8 μ In association with this decrease in red blood cell diameter, we have observed disc to sphere transformations in the red cells There was always some crenation in all of the samples The highest degree of crenation was observed in the samples with the highest concentration of Cholografin However, some small cells still appear to be discs During microscopy, aggregation of RBC was only rarely seen, and without any consistency in any particular samples

Table 4

Plasma hemoglobin values (mg) in 8 cases after exposure to different contrast media

Contrast medium	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
Control	9 5	18	30	8	25	3 5	12	1?
Cholografin in vivo 0 5 ml/kg body weight	36	25	42	?	20	2	61	18
Cholografin in vitro 0 13 mg%	6	21 5	39	5	20	5	14 5	21 5
Cholografin in vitro 0 86 mg %	860	41	246	44	21 5	8	1 350	100
Hypaque 50 % in vitro 0 13 mg%	6	11	39	8	21 5	5	11	16
Hypaque 50 in vitro 0 84 mg%	7	8	32	8	25	8	23	6
Hypaque 90 % in vitro 0 23 mg%	13	16	57 5	11	21 5	11	65	25
Hypaque 90 % in vitro 1 50 mg	16	46	44	8	25	5	55	21

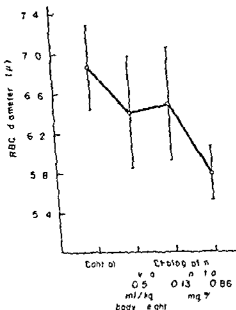


Fig 7 RBC diameters after exposure to Chlolografin Averages and S D s in 13 experiments

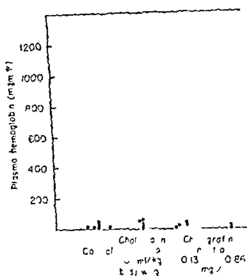


Fig 8 Plasma hemoglobin after exposure to Cholografin. Observations in 8 experiments

5 *Plasma hemoglobin* Plasma hemoglobin increased in a number of the 0 86 mg% Cholografin samples (Fig 8 and Table 4) In some instances, these were large increases indicating a great deal of red blood cell destruction

6 *Hematocrit* After 1/2 hour of centrifugation of the Hct tubes there was only a slight decrease of the hematocrit values in the in vitro Cholografin samples when compared to controls (Fig 9) After an additional half hour of spinning there was a remarkable decrease in the hematocrit of the higher Cholografin concentration (0 86 mg%) emphasizing the difficulties in packing discussed under RBC density This phenomenon was followed by examining the hematocrit tubes after five minute increments of centrifugation (Fig 10)

The hematocrits obtained following the injection of Cholografin in the animal after collection of blood for the in vitro samples were definitely higher than those in the Cholografin in vitro dilution samples In a few cases additional hematocrit controls were obtained immediately before the injection of Cholografin and showed that this increase was independent of the contrast medium injected

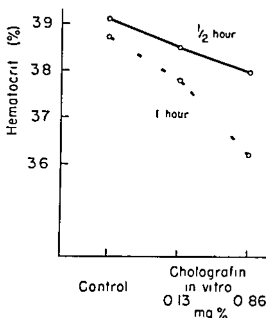


Fig 9 Hematocrit after in vitro exposure to Cholografin Comparison of 1/2 hour and one hour centrifugation Mean of 6 experiments

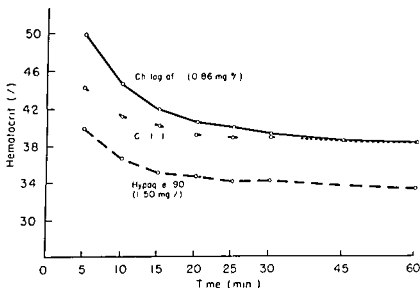


Fig 10 Hematocrit as observed after 5 minute increments of centrifugation at 2 500 rpm Average of 3 experiments

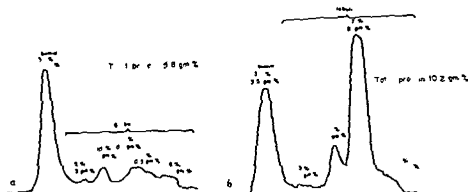


Fig 11 Serum electrophoresis (a) control and (b) after in vitro exposure of whole blood to Cholografin (Final conc 0 86 mg %) The two peaks which develop are due to (1) combination of haptoglobin and hemoglobin and (2) free hemoglobin

7 *RBC charge* Small decreases in RBC charge were noted in both the Cholografin in vitro dilution samples Considerably greater decreases in charge were noted in the post injection in vivo samples where the average of 13 observations indicated a mean negative charge of 1 46 × 10^{-8} Coulombs/cell as compared to a control mean of 1 64 × 10^{-8} Coulombs/cell

8 *Serum electrophoresis* In nine of twelve experiments analyzed there were large increases in the alpha 2 and beta globulin areas of the spectrum in the 0 86 mg % Cholografin samples In many instances these spikes were quite large even larger than the albumin area (Fig 11)

Controls in which Cholografin in the same concentration was combined with canine serum alone failed to show any electrophoretic changes, however Another group of experiments were then carried out in which duplicate electro-

Table 5

Sedimentation rates in mm hr after exposure to Cholografin and Hypaque (averages and extreme variations in 13 experiments)

Contrast medium	Sedimentation rate		
	Mean	Least	Greatest
Control	18 7	2	58
Cholografin in vivo 0 5 ml kg body weight	4 2	0	39
Cholografin in vitro 0 13 mg	8 7	0	49
Cholografin in vitro 0 86 mg	0	0	0
Hypaque 50 in vitro 0 13 mg	18 5	2	46
Hypaque 50 in vitro 0 84 mg	16 9	1 5	45
Hypaque 90 in vitro 0 23 mg	18 1	1	53
Hypaque 90 in vitro 1 50 mg	10 9	0 5	37

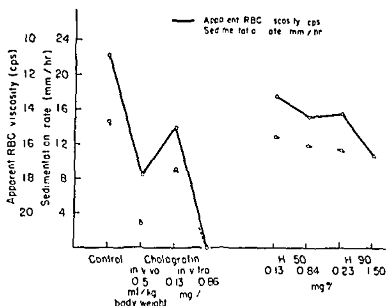


Fig 12 Sedimentation rates and apparent RBC viscosities Average of 6 experiments

phoresis strips were stained for the presence of hemoglobin with benzidine These revealed both of the globulin peaks to contain hemoglobin in large amounts — the first peak apparently resulting from a combination of haptoglobulin and hemoglobin, and the second from free hemoglobin alone

An additional electrophoresis experiment was carried out in which 6 % bovine serum albumin was used to prepare a 0 86 % Chologrfin solution This resulted in no detectable changes from the electrophoretic pattern of the albumin alone

B Hypaque

1 *Sedimentation rate* The mean sedimentation rates in 13 experiments, including data with both Hypaque and Chologrfin dilutions, are seen in Table 5 From the raw data, it was noted that the sedimentation rates of the 1 50 mg% Hypaque 90% dilutions were always lower, and often considerably lower, than controls, and the sedimentation rates of the 0 23 mg% Hypaque 90 % specimens were lower than the controls in the vast majority of cases The sedimentation rates in the 1 50 mg% Hypaque 90 % samples were lower than the sedimentation rates *in all other Hypaque samples in 11 of 13 instances*, and as low as any others in the other two As shown in Table 5, the decrease of the sedimentation rate in the Hypaque samples was considerably less than in the Chologrfin samples

Table 6

Sedimentation rates in mm hr after exposure to different contrast media (averages and extreme variations in 10 experiments)

Contrast medium	Sedimentation rate			LD_{50} mice
	Mean	Least	Greatest	mg/kg
1 Control	15 9	1	53	—
2 Cholografin 52	0 4	0	2	3 400
3 Hypaque 90	15 1	0 5	63	14 000
4 Renografin 76	12 1	1	37	11 000
5 Renovist 69	12 8	1	47	Not Available
6 Ditriokon 68	12 8	1	55	Not Available
7 Conray 60	13 8	1	48	17 000
8 Conray 80	11 8	0 5	45	17 300
9 Miokon 50	11 1	1	41	7 260
10 Urokon 70	0 9	0	4	7 700
11 Neo-Iopax 0	10 9	0 5	41	4 600
12 Diodrast 35	5 4	0 5	17	6 00

2 *Viscosity* There was no change in plasma viscosity with Hypaque dilutions There was an increase in both whole blood and apparent RBC viscosity in every instance The largest increases were in the 1 50 mg% Hypaque 90 % specimens However all of the apparent red blood cell viscosities and whole blood viscosities were smaller than those seen with the 0 86 mg% Cholografin samples

3 *Density* There was some increase both in plasma and RBC density in the 1 50 mg% Hypaque samples, but these changes were small However, all the plasma density values for these samples were higher than the values for plasma density in the Cholografin series The highest RBC density was always obtained in the Hypaque 90 % 1 50 mg% sample

4 The *RBC diameter* as an average, was somewhat smaller than the control diameter but was not strikingly different

5 The *plasma hemoglobin* did not change in most of the Hypaque samples and where there were changes they were much smaller than those observed with 0 86 mg% Cholografin (Table 4)

6 The *hematocrit* values decreased from the control results in both the 1 50 mg% Hypaque 90 % and the 0 84 mg% Hypaque 50 % samples This would appear to be due at least in part to osmotic forces (Fig 10)

There was only a slight decrease in the hematocrit values obtained after an additional half hour of spinning Thus there was no difficulty in packing the RBC s in a manner comparable to that seen with the 0 86 mg% Cholografin samples

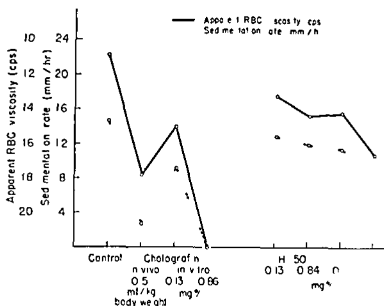


Fig 12 Sedimentation rates and apparent RBC viscosity of 6 experiments

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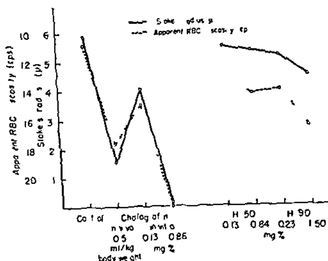


Fig 14 Stokes radius compared with apparent RBC viscosity Average of 6 experiments

changes observed by KAGSTROM et coll on the one hand and the changes in sedimentation rate on the other

Discussion

A profound decrease in erythrocyte sedimentation rate is a constant phenomenon following both in vitro and in vivo exposure of canine blood to methyl glucamine iodipamide and to a varying degree following in vitro exposure to other parenteral contrast media However an increased sedimentation rate is a common accompaniment of clinical intravascular RBC aggregation Recent studies have revealed that several parenteral contrast media including iodipamide cause intravascular aggregation That one drug can cause both intravascular aggregation and a decreased sedimentation rate has not been described previously to our knowledge

Changes in the sedimentation rate can hardly be discussed without considering the factors concerned in *Stokes law* The changes in the viscosity of the suspending medium the plasma are too small to result in a significant change in the sedimentation rate The size of the falling particles the red blood cells, is more difficult to evaluate The diameter of the cells is decreased particularly after exposure to high concentrations of Cholografin but since the cells seem to become more spherical the difference in size is probably not large enough to be responsible for the great differences observed in the sedimentation rate Furthermore our observations in vitro did not permit any estimate of the number or size of RBC aggregates If present however these would tend to increase rather than decrease the sedimentation rate

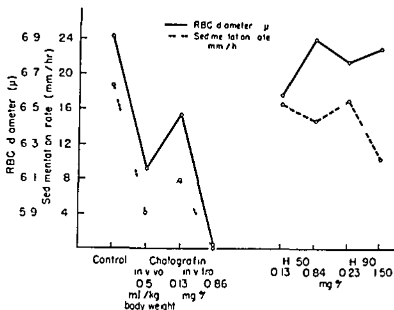


Fig 13 Sedimentation rates and RBC diameters Average of 13 experiments

7 The *RBC charge* was a little less than the control in most of the Hypaque samples but not significantly so There were no differences in charge between samples with different Hypaque concentrations

8 *Serum electrophoresis* revealed a few small changes in the beta and gamma globulin portion of the spectrum in Hypaque dilution samples However, these were never great, and in no way comparable to the magnitude of the changes seen with Cholografin dilutions

C Sedimentation rate series

Sedimentation rates were determined on heparinized mongrel canine blood with a variety of radiopaque compounds, including Cholografin 52 % Urokon 70 %, Neo Iopax 50 %, Diodrast 70 %, Hypaque 90 %, Renografin 76 %, Renovist 69 %, Conray 60 % and 80 %, Ditriokon 68 % and Miokon 50 % In these experiments, 0 02 ml contrast material was added to 5 ml blood, to approach a concentration between those used in the other parts of these investigations The data for these studies is presented in Table 6

In 8 out of 10 samples there was no observable sedimentation in the Cholografin samples Five samples with Urokon also had no observable sedimentation Diodrast also caused a considerable decrease in sedimentation rate Somewhat smaller decreases in sedimentation rate, as compared to controls, were seen with Neo Iopax and Miokon while the least changes were seen with Hypaque Renografin, Renovist and Conray There is a definite relationship between the toxicity of the contrast media, as expressed by the LD_{50} and the circulatory

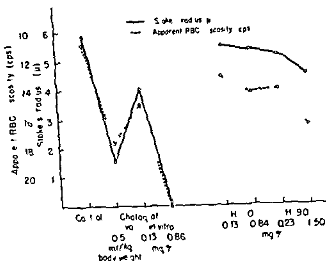


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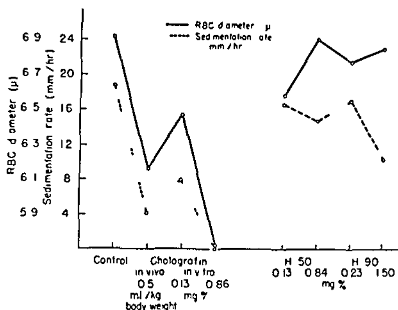


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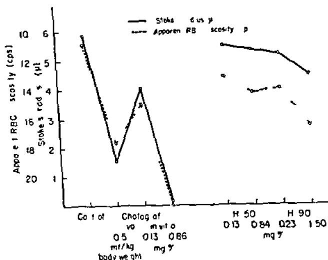


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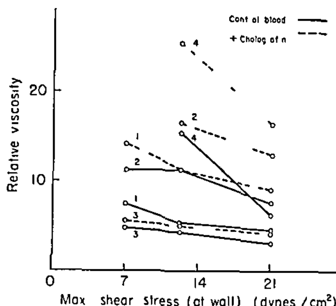


Fig 15 Relationship between relative whole blood viscosity and shear stress Data from 4 experiments

The most difficult factor to measure accurately is the difference in density between the falling particles and the suspending medium Our studies indicate that red blood cell density does not change appreciably, but that packing of the red blood cells is more difficult following exposure to iodipamide This may be interpreted as a decrease in 'effective' red blood cell density in its effect upon the sedimentation rate This density difference between RBC s and plasma is increased to the control sample level following prolonged centrifugation

It appears that parenteral contrast media, and especially iodipamide, affect red blood cells markedly All of the large changes observed (red blood cell viscosity, red blood cell density, red blood cell diameter) are not only directly related to the red blood cells but are consistent with the observed changes in sedimentation rate (Figs 12 and 13)

The highly variable hemoglobin values in the 0 86 mg% Cholografin samples are difficult to understand Technical errors due to defiling a common cause of unexpected hemolysis, seem to be improbable because of the fact that the highly increased plasma hemoglobin values occurred only in these particular samples It may be mentioned, however, that the blood groups of the dogs were not determined

A number of questions still remain open, however One is why the decreased sedimentation rate is associated with a process which, by intravital microscopy, looks like intravascular aggregation, and in every respect is like the aggregation typically associated with a high sedimentation rate, and another question is connected with the difficulties encountered in packing red blood

cells during centrifugation The present investigation does not provide any definite answers to these questions

Both the calculated Stokes radius which depends upon the factors in Stokes law and the apparent RBC viscosity which has as its basis entirely independent assumptions have been developed in an attempt to find a quantitative expression for intravascular aggregation Both should be proportional to the 'effective' RBC particle (cell or aggregate) size The striking reciprocal relationship of these two independent calculations under the conditions of this experiment (Fig 14) re emphasizes the lack of correlation between the sedimentation rate and intra vital microscopic observations

The observed sedimentation rate is the most important factor in calculating the equivalent or Stokes radius of the red blood cell implying that a high sedimentation rate is necessarily associated with an increase in RBC particle size, probably due to RBC aggregation However an additional factor of importance in these calculations is the difference in density between the red blood cells and the plasma In the 'Stokes' radius calculations the data for red blood cell density were obtained from the one hour hematocrit, which produced the greatest RBC packing and whole blood density data This means that the density difference used is a maximal one and the effective radius may actually be much larger The difficulties in packing RBC s which have been exposed to *iodopamide* may result in a marked reduction in the effective density difference between the plasma and the cells Under such circumstances even if large RBC particles (aggregates) are present their sedimentation rate may be greatly reduced and perhaps be unmeasurable This appears to be the *only plausible* explanation for the observed coincidental occurrence of intravascular aggregation and a low or absent sedimentation rate

The reason for the difficulties in packing is difficult to explain A possible hypothesis *could* be that the phenonemon is in some way related to the change in shape of the red blood cells with spherocytosis and crenation An indirect support for this hypothesis is the observation of E G EBBECKE and others that a spherocytosis decreases the sedimentation rate

The absence of sedimentation in the solutions with *more* Cholografin suggests that these suspensions may act at least when at rest like a single clump or aggregation This behavior and the accompanying *increase* in fluidity with motion are reminiscent of the phenomenon that PETERFI observed in his cell suspensions and named thixotropy It was first studied by measuring the Erstarrungszeit and then FREUNDLICH pointed *out* that the associated apparent viscosity tends to *increase greatly* with vanishing shear stress — with a sol to-gel type of transition

In order to verify this effect the blood from four dogs was measured directly and in admixture with Cholografin at three different stress levels in the capillary viscometer The results are shown *in Fig* 15 with the exception of the *one* control and the two Cholografin mixtures that were too viscous for reliable

measurement at the lowest stress level At least some evidence of thixotropy was found with all four blood samples and with the Cholografin mixtures, but no qualitative difference was found between the two types of suspension — perhaps because of the difficulties at lower shear stresses A good discussion of the dependence of thixotropy on charges and on the sizes and shape irregularities of suspended particles may be found in the book by PHILIPPOFF

SUMMARY

Simultaneous development of increased intravascular RBC aggregation and a marked decrease in erythrocyte sedimentation rate following iodipamide administration has been studied by measurements of certain physico chemical properties of blood including viscosity density, plasma hemoglobin RBC size shape packing rate and charge and serum electrophoresis Pertinent results include slight increases in plasma viscosity and density large increases in whole blood and apparent RBC viscosity decreased RBC diameter associated with crenation and spherocytosis difficulties in packing of the erythrocytes and inconstant but occasionally great hemolysis

ZUSAMMENFASSUNG

Die gleichzeitige Entwicklung von vergrosserter intravaskularer Erythrocytenaggregation und von verminderter Erythrocyten Sedimentierung nach Einspritzung von Iodipamid wurde mittels verschiedenen physiko chemischen Blutuntersuchungen studiert z B durch Ermittlung der Viskosität des Plasmahaemoglobins der Grosse der roten Blutkörperchen deren Form und Packung ihrer Ladung und mittels Serum Elektrophorese Wichtigere Resultate waren massige Vergrosserung der Plasmaviskosität und Dichte starke Vergrosserung der Gesamtblut viskosität und der anscheinliche Viskosität der Erythrocyten verminderter Durchmesser der RBC mit Sphärocytosis Packungsschwierigkeiten der Erythrocyten und inkonstanter aber oft starker Hämolyse

RÉSUMÉ

L apparition simultanée d une augmentation de l agrégation intravasculaire des globules rouges et d un ralentissement marqué de la vitesse de sédimentation après administration d iodipamide a été étudiée par la mesure de certaines propriétés physico chimiques du sang parmi lesquelles la viscosité l hémoglobine plasmatique les mensurations la forme et tassement et la charge des érythrocytes et l électrophorèse du sérum Les résultats de ces examens comprennent de légères augmentations de la viscosité et de la densité plasmatique d importantes augmentations de la viscosité du sang total et de la viscosité apparente des érythrocytes une diminution de leur diamètre avec crénation et sphérocytose le tassement d érythrocytes rendu difficile et une hémolyse inconstante mais parfois importante

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Illustrations of angiography in gross anomalies of the kidneys have previously been demonstrated by DOS SANTOS (1955) VOGLER & HERBST (1958) OLLE OLSSON (1961 1962)

Embryology Some knowledge of the embryology of the renal vasculature and structural development of the kidney is essential to the understanding of the multitude of anomalies that may occur With the complex development of the kidneys through the three stages of pronephros mesonephros and metanephros, and the migration of the kidney from the pelvis to the lumbar region, along with its longitudinal rotation and simultaneous acquisition of a vascular supply there is reason to understand why the possibility for anomalous development in the kidney may be greater than for other organs within the body Furthermore, because of the close communication between the two renal primordia in the fetal pelvis numerous fusion malformations may occur With the striking change in position a similar change in development and acquisition of a permanent blood supply also occurs At the time of the pronephros the blood supply is via a capillary network from pelvic vessels Along with degeneration of the proneph ros there is also absorption of the primitive vascular supply as multiple seg mentally arranged mesonephric arteries from the aorta form the rete arterios um urogenitale and eventually are responsible for the blood supply to the geni tourinary system Initially there are approximately 20 mesonephric arteries Ultimately only 3 branches that remain near the first and second lumbar seg ment become responsible for the blood supply to the adrenal gland and the kidney the upper two branches becoming the inferior phrenic source for the superior adrenal and the middle adrenal while the lower branch becomes the permanent artery for the kidney With this complex but simultaneous func tional interplay between the developing vasculature and structural develop ment of the kidney it is easily understood how anomalous development of the kidney is invariably associated with persistent embryologic vascular attach ments

Examination technic From the point of view of examination technic it is necessary in gross anomalies of the kidneys to perform aortic renal angiography This may in some cases be supplemented with suitable selective technics The aortic technic is necessary to evaluate the total vascularization of the anomalous kidney or kidneys Also the most distal part of the aorta and the iliac arteries must be represented since arteries to the anomalous kidney frequently have a caudal origin Different projections which generally include both oblique views are necessary in order to closely follow the course of the vessels and especially their entrance into the hilum The nephrographic phase must be well repre sented to make a thorough study of the renal parenchyma possible

Material The association of renal vascular abnormalities in connection with gross anomalies of the kidneys has been studied in 32 cases of gross renal anomalies in which renal angiography has been performed

FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR PROF OLLE OLSSON), LUND UNIVERSITY HOSPITAL, SWEDEN

VASCULAR ABNORMALITIES IN GROSS ANOMALIES OF KIDNEYS

by

OLLE OLSSON and MARK WHOLEY

Gross anomalies of the kidneys may change the roentgen anatomy to such a degree that pathologic changes may be difficult to diagnose or rule out according to prevalent criteria Furthermore these malformations have a higher incidence of calculous disease, inflammatory lesions and obstructive problems Occasionally the anomalies represent incidental findings of little clinical significance In many instances, however, they represent the important part for a decisive understanding of the pathologic and clinical symptomatology The information provided by urography and pyelography is frequently inadequate and for complete evaluation should be supplemented with angiography

By renal angiography it is possible to evaluate the vessel size, number and origin, as well as to study the size and shape of the kidneys for localization and type of the anomaly, and for demonstration of disease in the anomalous kidney Information of this nature is also valuable for another reason when contemplating segmental and reconstructive surgery, knowledge of the variational blood supply to an anomalous kidney is mandatory Finally, unless the roentgenologist is thoroughly familiar with these abnormalities he may encounter difficulties in the technical performance of the examination and in the interpretation of its result

Submitted for publication 13 December 1962



Fig 2 Right agenesia Left kidney malrotated (see shape of contrast filled pelvis) supplied by 3 arteries, one arising from iliac artery Laminated calcifications in small pelvis adjacent to urinary bladder No right kidney and no vessels to it (At operation a fluid filled sac was found on the right side in the small pelvis, containing clear fluid and stones)

irregularities and localized dilatations of the arcuate and interlobar arteries, as are commonly seen in pyelonephritis (BOLIN)

Classification and Discussion

Because of the complex embryologic origin many combinations of anomalous developmental possibilities exist This has resulted in considerable variation in classifications In many instances particularly in non functioning ectopia and in both the symmetrical and asymmetrical types of fusion classification by means of urography or pyelography with cystoscopy is not possible Total renal angiography has increased the possibilities of a close study of the gross anomalies and in all examples complete renal vascularization can be studied

Kidney anomalies may be briefly classified into four main groups

A Anomalies in number (agenesia supernumerary)
B Anomalies in position (ectopia malrotation)
C Anomalies in size and form (hypoplasia hypertrophy fusions)
D Anomalies in internal structure (polycystic sponge)

This brief system is intended as a guide rather than an extensive reference list Group D falls outside the scope of this paper Illustrative examples from the



Fig 1 Right agenesia Large left kidney supplied by 6 arteries two arising from caudal part of lumbar aorta and two from iliac artery

Malrotation is not included in this paper Our angiographic material of malrotation was studied by BOIJSEN (1959), and the reader is referred to his monograph on the anatomy of the renal arteries Multiplicity of renal arteries and veins per se are not included Our material of angiographically demonstrated multiple renal arteries has been studied by BOIJSEN in his above paper and their technical implications regarding the selective procedure by KOHLER (1963)

The distribution of the actual cases were as follows agenesia 6, ectopia 5, crossed ectopia (asymmetrical fusion) 3, horseshoe kidney (symmetrical fusion) 18

These numbers do not represent a true frequency They are highly influenced by the indications for renal angiography, which vary according to the clinical requirement in the specific case Indications for the examination were among others chronic calculous disease, pyelonephritis, hydronephrosis, non visibility of the anomalous kidney at urography, palpation of an abdominal mass

In the selection of cases, the hypoplasia group, for instance, was completely excluded because in many cases it is difficult to differentiate the contracted small kidney of atrophic pyelonephritis from hypoplasia (EMMET, ALVAREZ IERENA & MCDONALD 1952) This becomes more difficult as the hypoplastic kidney acquires secondary infection It may be that selective angiography is of differential value but so far our experience toward this possibility is limited We have for instance noted in our cases of hypoplasia that there is not the marked vascular irregularity or stenosis of the main arterial divisions, nor the terminal



Fig 4 Unusual type of ectopy low arterial connection which is of importance in s[illegible]lective angiography malrotation of slight degree

hypoplasia gastrointestinal atresias and Arnold Chiari malformations of the *central* nervous system The association of multiple anomalies is understandable *since these* structures develop at similar stages and any embryologic damage whether physical or genetic is likely to affect more than one system

A *group* in between complete agenesia and hypoplasia is represented by *cases* in which rudiments of a kidney is formed (see Fig 2) *In one* case irregular calcifications were seen on the left side, where *the kidney* should be located, and at pyelography a blind ureter was *found Renal* angiography showed no renal artery on this side On the right side a wide but single artery fed *the* hyperplastic kidney In the other case a large *sac containing* clear fluid with concrements was found in the small pelvis

The case *illustrated* in Fig 3 of bilateral changes is unique for several reasons This premature newborn baby was sent to *our hospital* on the eighth day after birth because of complete anuria At arrival in *our hospital* angiography was performed in order to find out if the anuria had a renal or post renal cause At aortography by catheterization after cut down and introduction of a thin catheter via one of the branches from the femoral artery no renal *arteries* and no renal parenchyma could be seen Roentgendiagnosis bilateral renal agenesia The patient died a week later *no* renal arteries were found at autopsy the kidneys were small and weighed 2 5 g each *Microscopically* the kidneys contained fibrous tissue with a few primitive glomeruli

A fetus with bilateral agenesia can live intrauterinely because of the artifical kidney that the placenta provides The extrauterine life time *is short* POTTER in her textbook on pedia



Fig. 3. Bilateral agenesia in a 8 day old infant, frontal and oblique views. No renal arteries.

other groups will be given with special regard to the vascular component in the anomaly.

Renal agenesia (6 cases, Figs. 1—3) is characterized by complete failure of the nephrogenic tissue to show any potentiality of organogenesis. As a result, the pronephros, mesonephros or metanephros do not form a definite kidney or its rudiment. The ureteric orifice, ureter and renal artery are also absent. In our two cases of agenesia on the right, the malformation apparently extended to the genital section of the nephrogenic ridge since there was associated anomalous development of the uterus. The left kidney was hypertrophied and malrotated and supplied by 3 arteries in one case and 6 in the other case. In a case of leftsided agenesia 5 arteries supplied the hypertrophic right kidney. In 2 other cases, one of the arteries arose from the common iliac artery and in the other several arteries arose from the iliac in its most distal section. In only 2 cases was the solitary kidney fed by a single renal artery and no abnormalities were present except the absence of the contralateral kidney and its vessels.

In many instances the embryologic malformation also extends to the upper end of the nephrogenic ridge with congenital absence of the ipsilateral adrenal gland. It was not possible to demonstrate ipsilateral adrenal filling in our cases.

The association of combined renal and other anomalous organ development is well documented. Renal agenesia is frequently associated with pulmonary



Fig 6 a) Arterial b) nephrographic phase Crossed ectopy and complete fusion to the left of the mid line Stone in upper renal pelvis multiple renal arteries some arising from both iliac arteries

Multiple vessels were present in all our cases and in one example the upper normal segment on the left received aortic branches while the ectopic segment received its blood supply via a branch from the opposite common iliac artery In another example the ectopic right kidney crossed at the level of the sacrum and was fused to an ectopic left kidney Multiple arteries to the left kidney were present One arose from the aorta near its bifurcation the left external and internal iliac supplied the remainder The ectopic segment near the sacrum received its blood supply via two branches from the right common iliac artery Vessel size varied from 1 5 mm to 7 5 mm In the patients with crossed ectopia and asymmetrical fusion the ectopic segment was not well demonstrated at urography but could be demonstrated in detail at angiography in the nephrographic phase The asymmetrical fusion was longitudinal in two examples and horizontal (sigmoid kidney) in the other The ectopic section demonstrated fetal lobulation

The etiology of crossed ectopia is not quite clear and several theories have been proposed POTTER (1952) suggested that the ureteric bud on one side wanders across to the other side and stimulates the opposite metanephros to



Fig 3 a) Arterial phase b) nephrographic phase Marked caudal ectopy on both sides malrotation right kidney medially located no fusion The arterial supply to the kidney derives from lower parts of aorta and iliac arteries arteriosclerotic changes in the latter

tric pathology reports a survival of maximum 11 hours for babies with bilateral agenesia but longer survival is possible Our patient lived for two weeks The diagnosis was firmly established at angiography This as far as we know is the first diagnosis of this type

Renal ectopia (8 cases, Figs 4 and 5) Five cases were ipsilateral ectopia In one patient, in which the renal artery was at the level of L 3, the kidney size was normal, this was the highest position for an ectopic kidney in this series Three cases were examples of crossed ectopia with fusion (asymmetrical fusion) The ectopic kidney was lobulated in 2 cases, and in 4 it was smaller than normal Malrotation of different degree with the hilum directed anteriorly was present in all the cases A case described by JONSSON & OLSSON (1962) falls into this category

There was a direct relationship between the degree of maturity and the fetal ascent of the kidney Although the more mature ectopic kidneys may retain primitive pelvic vascular attachments to their lower pole, the main renal artery invariably arose from the aorta In contrast, the very immature ectopic kidneys were low in the pelvis and vascularized entirely by pelvic vessels

During the angiographic examination the problem of differentiating the ectopic kidney from degrees of nephroptosis never occurs since the ectopic kidney always has an anomalous blood supply as well as a characteristic short ureter



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form additional renal tissue. WILMER (1938) suggested that formation of renal tissue occurs on the normal side but is forced across to the opposite side by the pressure of the umbilical arteries. ASHLEY (1960) proposed an absence of all metanephric tissue on one side with positive attraction by the metanephros on the opposite side for both the arteries. It is based on the idea of positive attracting forces within the developing embryo. Certainly, before this migration occurs, *the blood supply which is intended as temporary is established from branch*es ultimately to be the iliac vessels, middle sacral and pelvic branches. With interference in migration these temporary attachments become the permanent blood supply. After the temporary vessels become permanent they further fix and inhibit upward migration of the kidney.

We encountered no examples of crossed ectopia without fusion, which generally occurs in less than 10 % of all cases of crossed ectopia. This absence of fusion usually can be evaluated only during the nephrographic phase of angiography.

Horseshoe type kidney. In the present series there were 18 cases of symmetrical fusion and classified as horseshoe type kidney. In all instances the connecting bridge was at the lower pole and crossed in the region of the third to fifth lumbar vertebrae. Considerable variation in the amount of functioning parenchyma at the connection was shown.

Suitable projections of the nephrographic phase are necessary to demonstrate *the size of the bridge and whether or not the union is fibrous or parenchymal.*

There also was a considerable variation in the shape of the fused kidneys from entirely symmetrical kidneys to more or less marked asymmetry. Angiographic findings in kidneys of the symmetric type are illustrated in Fig. 8. Further cases from our material can be found in two previous papers by OLSSON (1961, 1962) with illustrations of slight and marked asymmetry of a horseshoe kidney. Fig. 6 may represent a horseshoe kidney with the highest degree of asymmetry.

The etiology for this anomaly is not fully explained but it has been suggested that the two renal primordia fuse medially at about the fifth week. The two primordia which normally lie close together in the pelvis are forced together during their ascent by the converging umbilical arteries. The fusion then prevents rotation and the pelves and hila are directed anteriorly instead of medially. Furthermore, since there is always combined interference with ascent, the horseshoe kidney is always situated lower than normal.

Along with interference in ascent is an associated anomalous blood supply. Similar to the vasculature in ectopia, the originally intended temporary vessels from the pelvis become the permanent supply. In our experience, the total number of vessels varies from 4 to 7 and the vessel size from 2 mm to 8 mm. The vessels varied *in origin from the aorta at the level of the 12th thoracic* vertebrae to the internal iliac artery at the lower level. In all instances, at least one vessel arose from either the common or internal iliac artery. The latter ves



Fig. 7 a) Pyelogram lower kidney b) urogram c) angiography arterial phase d) nephrographic phase. Crossed ectopy right side kidneys well outlined against one another but in close contact. Caudal kidney rotated with hilum facing laterally-caudally. Five renal arteries two arising from low aortic segment and two from right iliac artery distal branches of last mentioned make a sharp bend when entering into the abnormally positioned hilum of the lower kidney



a

Fig 8 Symmetrical fusion and two kidneys on left side a) Urography Shape of kidneys and kidney pelves characteristic of horseshoe kidney marked dilatation of right kidney pelvis b) Angiography arterial phase Multiple renal arteries blood supply to lower left kidney from branch of proximal part of left iliac artery c) Nephrographic phase fused kidneys well distinguishable In right kidney marked reduction of parenchyma caudal poles of lower left kidney and right kidney deviating medially no parenchymal fusion



b



c

sels always supplied the lower pole segments or the connecting parenchymal isthmus All of the patients had secondary pathologic conditions related to the fusion or the vascular abnormalities Most commonly this was calculous disease, pyelonephritis or hypertension In one instance, a carcinoma of the renal pelvis was present and was demonstrable angiographically (Boijsen & Folin 1961) This high incidence of secondary pathologic findings is related to three factors the abnormal course and insertion of the ureters, which interfere with proper drainage, the multiple arteries which may further obstruct and produce hydronephrosis, the firm fusion which interferes with mobility and further may decrease renal circulation

Conclusion

There exists a complex and intimate connection in structural development of the kidney and its arterial system The basic point embryologically is that the kidney from a low site of origin ascends to a higher permanent lumbar position

During the migration, the kidney moves from one anatomic vascular environment to another one which is considerably different. A rich supply of provisory connections from the aorta to the mesonephros is supplanted by one single definitive artery to the metanephros. Aberrations from normal development easily and constantly will effect this intricate interplay between the organ and its functional connections to the body.

According to our experience gross anomalies of the kidneys always exhibit vascular abnormalities. Thirtytwo cases of anomalous renal development were reviewed and in all instances except in aplasia multiple arteries were present. Vessels started at abnormal sites and ran an abnormal course. In all our cases of malrotation (inhibited rotation) also multiplicity of the arterial supply to the malrotated kidney was demonstrable.

Angiography clarifies the anatomy and pathology in cases in which the anomaly makes ordinary diagnostic pyelographic criteria debatable. This is especially true for tumor involvement in the anomalous segment. The malformed kidney is also predisposed to a higher incidence of secondary acquired infectious disease. These frequently affect the parenchyma and angiography will demonstrate the degree of involvement better than any other method. Angiography also provides detailed vascular anatomy of importance in the planning of surgery. Many times the abnormality including the anomalous vasculature is the cause of obscure symptoms not possible to clarify with ordinary conventional procedures. Consequently the indications for renal angiography in anomalous development of the kidney should be expanded.

SUMMARY

Gross anomalies of the kidneys always exhibit vascular abnormalities. Indications for renal angiography in abnormal development of the kidney should in many respects be expanded in order to increase the diagnostic acumen.

ZUSAMMENFASSUNG

Grobere Missbildungen der Nieren zeigen stets ebenfalls Missbildungen der Gefasse. In solchen Fallen ist folglich immer die Indikation fur renale Angiographie gegeben, so dass eine akkurate Diagnose gestellt werden kann.

RÉSUMÉ

Les anomalies macroscopiques des reins comportent toujours des anomalies vasculaires. Les indications de l'angiographie rénale dans les cas d'anomalie de développement des reins devraient etre portées plus largement pour augmenter la finesse du diagnostic.

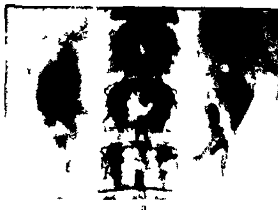


Fig 8 Symmetrical fusion and two kidneys on left side a) Urography Shape of kidneys and kidney pelves characteristic of horseshoe kidney marked dilatation of right kidney pelvis b) Angiography arterial phase Multiple renal arteries blood supply to lower left kidney from branch of proximal part of left iliac artery c) Nephrographic phase fused kidneys well distinguishable In right kidney marked reduction of parenchyma caudal poles of lower left kidney and right kidney deviating medially no parenchymal fusion





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FROM THE RADIATION PHYSICS DEPARTMENT, THE ROENTGENDIAGNOSTIC DEPARTMENT AND THE INSTITUTE OF PHYSIOLOGY, UNIVERSITY OF LUND, SWEDEN

RENAL FUNCTION TESTS WITH RADIOACTIVE DIODRAST IN DOGS

by

B BODFORSS T MUTH and T OLIN

Clearance tests are now widely performed in the estimation of renal function One of the most commonly used test materials is diodrast (iodopyracet) Determinations are made of the concentration of the test substance in the plasma and in the urine as well as of the volume of urine excreted during a definite period the so called clearance period Clearance of a substance is defined as the number of millilitres of plasma cleared of the substance on its passage through the kidneys per minute Clearance $= \frac{U\ V}{P}$ (P = concentration in plasma U = concentration in urine V = volume of urine, SMITH 1951 Chapt III)

The clearance period must often be fairly long (about 15 minutes) to allow collection of sufficient amounts of urine for analysis and to reduce the effect of the dead space in the renal pelves and ureters It is therefore desirable to maintain a constant concentration of the test substance in the blood for a long period For this purpose GOLDRING CHASIS RANGES & SMITH (1940) infused diodrast intravenously at a low rate FOA & FOA (1942) on the other hand,

A preliminary report of this work was presented at the meeting of The Nordic Society for Medical Radiology Lund June 1961 Submitted for publication 28 December 1962

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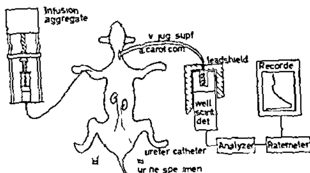


Fig 1 Method I An arteriovenous measuring coil connected between common carotid artery and superficial jugular vein The concentration of radioactive diodrast in the blood is kept at a constant level with the infusion aggregate guided by an immediate analysis obtained from the recorder Urine is collected from the right and left ureters selectively

renal vein has been described by WARREN, BRANNON & MERRILL (1944) Somewhat modified forms of this method have been widely used particularly in recent years According to the extraction method determinations are made of the concentration of the test substance in the arterial blood and in the venous blood of the kidney The extraction capacity of the kidney is defined by the formula $E = \frac{A - V}{A}$ where E = extraction A = concentration of substance in arterial blood and V = concentration of substance in blood from renal vein Thus on complete extraction, E = 1 or expressed as a percentage, 100

Diodrast is eliminated by glomerular filtration and tubular excretion, predominantly by filtration if the concentration in the blood is high and chiefly by tubular excretion if it is low The rate of elimination of diodrast into the urine is thus a measure of the total capacity of the glomeruli and tubules to clear the blood of a known content of the test substance (For details see SMITH 1951 Chapt VI)

Radioactively tagged test substances may also be used with advantage in such renal clearance tests their use simplifying and accelerating the analysis and giving more reliable results MAC INTYRE & LEONARDS (1955) determined the rate of excretion by continuous registration of changes in the blood concentration of different tagged test substances in an extracorporal arteriovenous shunt over a scintillation detector

The writers have elaborated two renal function tests based on the use of ^{131}I tagged diodrast for experimental and clinical purposes one for the determination of clearance and one for that of extraction (Radioactive Hippuran is now available and may be used instead of diodrast)

gave a relatively large dose of diodrast by rapid intravenous injection and claimed that following a certain interval after the injection the concentration of diodrast in the blood decreases so slowly that the value found for a blood sample collected in the middle of the clearance period may be regarded as approximately representative of the entire clearance period Attempts have also been made to secure a steady concentration of the substance in the blood by injecting the material subcutaneously (FINDLEY & WHITE 1940, HILDEN 1943, 1946) or intramuscularly (JOSEPHSON 1944) More recent investigators have recommended a priming dose followed by slow intravenous infusion of the clearance substance to compensate for the amount eliminated by the kidneys during the measuring period (BILLION & SCHLUNGBAUM 1955, LINDELL & OLIN 1957, EDVALL 1958, BERGSTROM, BUCHT & JOSEPHSON 1959) With the procedure described it is difficult to maintain a constant suitable concentration of the test substance in the blood during the clearance period The concentration of the test substance may therefore fall outside the desired range, particularly in the presence of impaired renal function Since such over or under dosage is not detectable until the test has been concluded, the dose cannot be adjusted during the actual examination, in such cases the test must sometimes be repeated with a more suitable amount of medium

Measurement of the concentration may however be facilitated by the use of radioactively tagged test substances such as diodrast (BILLION & SCHLUNGBAUM 1955, SCHLUNGBAUM & BILLION 1956, BERGSTROM, BUCHT & JOSEPHSON 1959)

Determinations in conventional clearance studies are made also of the amount of bladder urine, i e the amount excreted by both kidneys, as well as of the concentration of the test substance in the bladder urine The clearance capacity of each kidney may however be estimated by catheterizing each ureter and collecting the urine from the right and left side separately (CHASIS, REDISH & ERDMAN 1940 and later by several other authors, in Sweden among others by EDVALL 1958) This method, however, has certain disadvantages Thus, owing to leakage along the outer wall of the catheter, it is often difficult to collect all the urine from the ureter In addition, catheterization may disturb the peristalsis of the ureter, and consequently the pressure prevailing in the renal pelvis, and produce a reflex effect on renal function and renal blood flow Nor can the method be used in patients with renal damage, with hematuria, or with ureteric obstruction Finally, catheterization of the ureter involves the risk of mucosal injury and infection

Information may however be obtained on the function of each kidney separately without catheterization of the ureters A method assessing the capacity of the kidney to extract a test substance from the blood has been used by, e g WHITE (1940), CORCORAN, SMITH & PAGE (1941) who explanted the kidneys subcutaneously in dogs and collected blood samples by direct puncture of the renal veins A catheterization method for obtaining blood from the

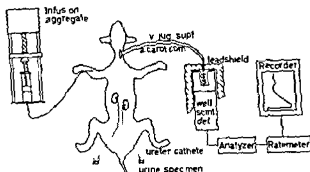


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Table 1

Clearance for right and left kidney determined selectively with method I

Exp H 12 ♂ weight 14 kg	Urine specimen nr	ml	Diodrast clearance in ml plasma per min
Left	1	2 5	124
	2	2 5	138
Right	1	2.3	121
	2	2 4	131

The injection of diodrast could thus easily be adjusted to a suitable rate A servo system for this purpose is under consideration

Experimental The dogs were anaesthetized with about 30 mg/kg bodyweight pentobarbital sodium U S P (mebumalnatrium 6 % ACO) intravenously Light anaesthesia was then maintained by administration of small supplementary doses During preparation the animal was placed on its back but during the actual investigation on one side The dogs were given heparin in a dose of 2 to 2 5 mg/kg bodyweight The rectal temperature was recorded continuously and kept constant during the examination by the use of an electric radiator short haired animals often required such warming The dogs which had been deprived of food for about 12 hours before the test, were given up to 600 ml of 5 5 % glucose intravenously, slowly, before sampling in order to maintain satisfactory diuresis The blood pressure was recorded with a mercury manometer via a polythene catheter inserted into an artery The hematocrit was measured during the experiment by a micromethod

The common carotid artery and the superficial jugular vein on one side were ligated cranially, and a polythene catheter (during the latter part of the investigation a teflon catheter) of suitable caliber (PE 240 O D/I D = = 2 42/1 67 mm) was introduced in a proximal direction into each vessel The two tubes were connected extracorporeally to form an arteriovenous shunt through the measuring coil The distal portions of the ureters were surgically exposed and a polythene catheter was passed a short distance up each ureter where it was fixed in position with a ligature The wounds were closed and urine from each kidney was conducted through the catheters into separate containers (Fig 1)

About 125 to 175 mg/kg bodyweight diodrast in the form of a mixture of inactive and radioactive substance of known specific activity was first injected intravenously as a priming dose The concentration of diodrast in the blood was recorded continuously from the moment of injection when it had fallen to the desired level e g 10 mg/100 ml (usually 15 to 20 minutes after injection of the priming dose) an intravenous maintainance dose of tagged diodrast was started with the apparatus for controlled infusion Urine was collected for 15

Fig. 2. Concentration of radioactive diodrast in blood after a priming dose given at time 0. Time to be read from right to left. Continuous infusion is started at about 16 min. Range changed in left hand curve; after some initial jerks the concentration is adjusted to a constant level and urine is collected for clearance determination.

Method I

General principle. The conventional method for determining diodrast clearance was improved by continuous registration of the concentration of the diodrast in arterial blood, enabling adjustment of the rate of intravenous injection of the maintenance dose of diodrast necessary to keep the concentration of the substance in the blood constant.

Apparatus. An arteriovenous shunt was established between the common carotid artery and the superficial jugular vein and consisted of a polythene tube (for details, see below under 'experimental'). This coil, with an effective volume of about 1 ml, was placed in a scintillation counter of the well type, connected to an analyzer, a ratemeter and a recorder. The scintillation crystal must be placed relatively close to the animal because a long connection to the coil favours coagulation. In order to reduce background the crystal was enclosed in a lead shield with only a small hole at the top to receive the two shanks of the coil. However, since ^{131}I emits about 10 % of its gamma radiation at high energy (640 and 720 keV), a varying background may be obtained. This is, however, decreased considerably by selective measurement of the main gamma energy of ^{131}I (364 keV). The test substance used consisted of ^{131}I tagged diodrast (Abbott) (0.1 μC ^{131}I per mg diodrast) diluted with inactive iodopyracet (Umbradil 35 %, Astra). The number of impulses produced by a certain (predetermined) amount of tagged diodrast in mg/100 ml in the coil was determined. This was used for measuring the absolute concentration of diodrast in the blood throughout the experiment. The polythene coil was afterwards rinsed with physiologic saline and the background was determined. The standard and background were checked after every experiment. An apparatus for controlled infusion was used in order to maintain constant blood concentration during the experiment (CLEMENTZ & OLIN 1961).

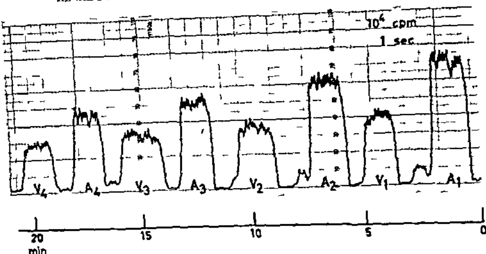


Fig 4 Alternate measurement of concentration of diodrast in blood from the aorta (A) and right renal vein (V) by method II

the solution for perfusion for instance RISA (BODFORSS, CEDERQUIST DAHLBACK 1962)

Method II

General principle The extraction capacity of the kidneys was studied after an intravenous injection of radioactive diodrast by continuously recording the concentration of the radioactive substance in the blood in the aorta and a renal vein

Apparatus The apparatus and the calibration were essentially the same as those for method I Besides a ratemeter and recorder, a counter was used to increase the statistical accuracy in the measurement of the relatively low concentration in the blood in the renal vein especially towards the end of the experiment The number of impulses was counted for at least one minute in each test or if the concentrations were very low until 1 000 impulses had been registered

The system was provided with a 3 way cock to enable alternate measurements of arterial and renal vein blood in the same scintillation detector (Fig 3) The sample measured could thus be injected back into the blood stream and the blood volume and blood pressure thereby kept practically constant The coil was rinsed with physiologic saline between the different samples to obtain a base line counting rate corresponding to the background (Fig 4)

The return flow of blood in one dog was rendered automatic with a double coil pump The concentration of radioactive diodrast both in the arterial and the renal venous blood was thus continuously recorded by duplicating the recording equipment

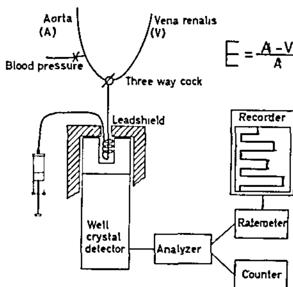


Fig 3 Method II Determination of extraction of radioactive diodrast from the blood Blood is drawn alternately from the aorta and the renal vein to the measuring coil through a 3 way cock

minute periods in the usual way when the desired constant concentration of diodrast in the blood was established The volumes of urine were measured, and the diodrast concentration in the urine was determined later in the scintillation detector

Material The method was tried in 4 dogs, in 2 of the animals clearance studies were performed selectively on both sides The stable concentration of diodrast in the blood during the measuring period is apparent from Fig 2, and Table I gives the clearance determinations made by this method

Conclusion The system with the closed arteriovenous shunt is simple and reliable, the volume of the blood sample and its geometric relationship with the scintillation detector is constant throughout, and the continuous registration makes it possible to hold the concentration level constant within $\pm 5\%$ It therefore enables experiments with a predetermined concentration of test substance in the blood

The method for examining the capacity of an organ to eliminate a radioactive substance from the blood, where it is kept at a constant level by continuous infusion, may also be used with advantage in the examination of organs other than the kidneys

Our device with an arteriovenous measuring coil may be used to detect leakage into the general circulation while treating a tumor in an organ by local perfusion A small amount of a suitable radioactive substance is then mixed in

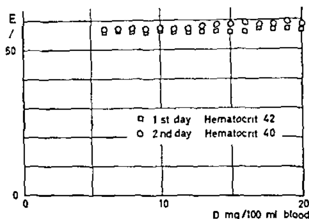


Fig 6 Extraction (E) of diodrast (D) from arterial blood by the right kidney on two successive days

vena cava (BRADLEY 1948) (Fig 5) It was sometimes difficult to introduce the tip of the catheter into the renal vein when the latter had valves at its entry into the inferior vena cava, the occurrence of such valves has also been described by GILLOT HURREAU AARON & TOUBOUL (1962)

Material and Results Twenty three dogs were examined with this method Two of the animals were examined on two successive days (Fig 6 shows one of them)

It was possible to calculate the extraction of diodrast from the whole blood from the curves (Fig 7) at any concentration used, but to enable comparison of the values obtained in the various animals, the extraction was calculated for a concentration of 10 mg per 100 ml blood The statistical error of the single observation was 5 %

The material was divided into two groups according to the microscopic appearance of the kidneys (Table 2) because dogs especially old female dogs

Table 2

Extraction of diodrast from whole blood Group 1 by normal kidneys — Group 2 by kidneys with pyelonephritic changes

Group	Histology	Number of dogs	Extraction Range	Mean
1	No pathologic findings	15	0 50—0 61	0 55
2	Pyelonephritis of various degrees of severity	8	0 37—0 46	0 42



Fig 5 Inferior vena cava filled with barium suspension Both renal veins with their arborizations are filled and on the left side the upper part of the spermatic vein is filled where it enters the renal vein

Experimental The dogs were prepared in the same way as that described under method I with the exception that the ureters were not dissected free The femoral artery and vein were however freed on one side, usually the right, some centimeters below the inguinal ligament, and were ligated distally A catheter was introduced into the artery and then passed on until its tip was situated in the abdominal aorta, after which the catheter was fixed in position A radiopaque catheter (Kifa, No 1 O D /I D = 2 2/1 2 mm), provided with 2 sideholes close to the tip, was introduced into the vein and passed into the inferior vena cava The curved end of the catheter was then introduced into the renal vein (RAPPAPORT 1952, HELANDER, ÅSHEIM & ÖDMAN 1958) The renal veins empty into the inferior vena cava at the level of L1— L2, *if the catheter is passed still further up, it will often enter a* hepatic vein The catheter was sometimes passed into a common trunk of two united lumbar veins or the phrenic abdominal (lumbo abdominal) vein (ELLENBERGER & BAUM 1891) To ensure that the tip of the catheter was situated in the renal vein, 2 ml Thorotrast were injected and a roentgenogram obtained This contrast medium is not excreted by the kidneys and will thus not disturb the excretion of the diodrast, it is only slightly radioactive and does not disturb the measurements by the scintillation detector When only one of the kidneys was to be studied, the right was selected because the spermatic or ovarian veins often empty into the renal vein on the left side, while the corresponding vessels on the right side empty directly into the inferior

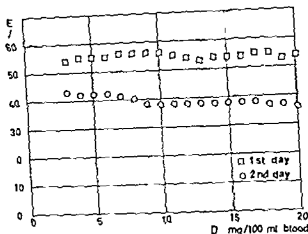


Fig 8 Extraction (E) of diodrast (D) from blood by the right kidney before and one day after damage caused by a large dose of contrast medium deposited in right renal artery

diodrast was determined chemically WHITE reported that the extraction from whole blood varied between 0 46 and 0 66 (mean 0 57) at a diodrast concentration below 13 mg iodine/100 ml plasma i e less than 26 mg diodrast/100 ml plasma CORCORAN, SMITH & PAGE reported a range of 0 64 to 0 82 (mean 0 707) measured in whole blood but at a lower blood concentration than those given by WHITE The authors do not however, state from which kidney the samples were collected It is not difficult to obtain reliable samples from the right side samples may also be obtained from the left side provided the catheter is advanced far enough towards the renal hilum past the opening of the left spermatic or ovarian vein (EDVALL 1958)

The values arrived at for the clearance of whole blood will be lower than those found for plasma since some diodrast also occurs in the red blood cells, but the difference between the concentration of the test substance in arterial and venous blood from the kidney corresponds to the amount of diodrast extracted by the kidney

Several authors including WARREN BRANNON & MERRILL (1944) have found a correlation between diodrast and PAH (p aminohippuric acid) regarding both extraction and clearance (see also SMITH 1951, Chapt VI) The extraction value for PAH is higher because PAH probably does not enter the red blood cells to the same extent as diodrast Both substances are eliminated in the same way i e by glomerular filtration and tubular excretion A very important question is the degree of reliability of the extraction values as a measure of the functional capacity of the kidney The test is more difficult to interpret in the presence of isolated local renal lesions but if the lesions are gener

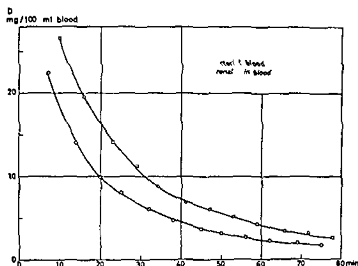


Fig 7 The concentration of diodrast (D) in arterial blood and in renal vein blood after a single intravenous injection is followed according to method II

often have pyelonephritis, relatively young male dogs were therefore used as far as possible

Conclusion Method II not only enables continuous registration of the concentration of the test substance in the blood, but also simplifies estimation of the extraction rate and avoids the source of error inherent in the otherwise necessary separation of the blood cells from the plasma The red blood cells contain diodrast in relatively higher concentration in blood from the renal vein, since the concentration of diodrast in the plasma decreases during its passage through the kidneys The diffusion equilibrium is thus disturbed and the diodrast in this blood escapes from the blood cells to the plasma If the blood sample is not centrifuged immediately after sampling, the concentration of diodrast in the plasma will thus increase and the clearance capacity of the kidney will be falsely low (WHITE 1940)

With the method described, several samples may be studied at short intervals without disturbing the composition of the blood, i e without any transient reduction in the hematocrit, which often occurs after repeated withdrawal of separate blood samples, especially in small animals Since diodrast, as mentioned, also enters the red blood cells, the ratio between the amount of diodrast in the red cells and that in the plasma will vary with the hematocrit value of the sample It will also probably vary to some extent with the protein content of the plasma (SMITH & SMITH 1938, BLOCK & BURROWS 1960)

Extraction of diodrast has been studied in dogs with subcutaneously explanted kidneys (WHITE 1940, CORCORAN, SMITH & PAGE 1941) Blood samples from the renal vein were collected by puncture and the concentration of

Both methods (I and II) were elaborated and tried on dogs under anaesthesia with pentobarbital sodium U S P In view of the effect of such drugs on the kidneys the anaesthesia was kept as light as possible and was usually maintained for a period of less than two hours GLAUSER & SELKURT (1952) claimed that deep prolonged anaesthesia with barbiturates impairs renal circulation probably owing to constriction of the arterioles and possibly also to a direct effect on the renal tubuli Light anaesthesia with barbiturates and of less than three hours duration is however not believed to influence renal function

If the anaesthesia is too deep and respiration markedly impaired the extraction capacity of the kidney is reduced This is exemplified by the results of the experiment shown in Fig 9, in which respiration was depressed so much that the arterial blood was dark at the same time the extraction fell to zero but returned to normal values as soon as the respiratory difficulties had been controlled

Acknowledgements

The authors are greatly indebted to Prosektor N O Berg for the histologic examination of the kidneys and to Dr C O Delin and Mrs Margit Prytz (AB Draco) for technical assistance

SUMMARY

Renal function was investigated with ^{131}I tagged diodrast in the dog by using an arteriovenous measuring coil and recording the concentration of the substances continuously and by studying the functional capacity of each kidney by measurement of the concentration of tagged diodrast in the aorta and a renal vein

ZUSAMMENFASSUNG

Die Nierenfunktion wurde an Hunden mittels ^{131}I enthaltendem Diotrast überprüft durch kontinuierliche Konzentrationsmessung der radioaktiven Substanz in einer arteriovenösen Anastomose und durch Ermittlung der Funktionsausbeute jeder einzelnen Niere mit Hilfe von Konzentrationsbestimmungen des markierten Kontrastmittels in der Aorta und der jeweiligen Nierenvene

RÉSUMÉ

La fonction rénale a été étudiée chez le chien avec du diodrast marqué a l iode 131 au moyen d un serpentin de mesure artérioveineux et en enregistrant de façon continue la concentration de ce corps et en étudiant la capacité fonctionelle de chaque rein par la mesure de la concentration en d odrast marqué dans l aorte et dans une veine renale

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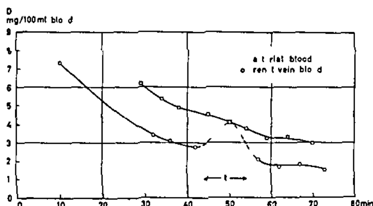


Fig. 9. Concentration of diodrast (D) in arterial and renal vein blood. Respiration deeply depressed during the time (t) because of an overdose of pentobarbital sodium.

alized, such as in conditions caused by blood borne agents acting upon the entire kidney, the correlation is probably more reliable (EDVALL 1958).

The writers have tried the method on kidneys exposed to contrast media deposited selectively into one of the renal arteries. The results, which were correlated with the histologic picture, were convincing and will be the subject of a future paper. It will be sufficient to give an illustrative example (Fig. 8) of a case with histologically verified injury and low extraction.

The accuracy and reproducibility of the method are apparent from Fig. 6, where the extraction was determined on 2 consecutive days without the kidney being subjected to chemical or mechanical injury between the tests. The extraction and HCT during this period thus proved constant.

Discussion

As mentioned above, it is necessary to keep the composition of the blood, HCT and the plasma protein, as constant as possible from one examination to the other. This was exemplified by the observation made in a dog that had had a gastric fistula for a year. The animal was thin and very anemic, with 19 HCT. The extraction found at the first examination was 0.61, i. e. the upper limit of the normal range in the series. After withdrawal of a moderate amount of blood the HCT a day later was only 16, while the extraction value was now about 0.75 for the same concentration of diodrast in the blood. The extraction was 0.43 and the hematocrit 48 in another dog, owing to an accident, a fairly large amount of blood was lost during the experiment, and five days later the HCT was 38 but the extraction had increased to 0.69. This phenomenon may probably be explained by the assumption that the amount of diodrast dissolved in the plasma, and readily available for excretion via the kidneys, increases with decreasing HCT and blood protein content.

BOOK REVIEWS

DIE MYELOGRAPHIE MIT POSITIVER KONTRASTMITTELN Von J WELLAUER G Thieme Verlag Stuttgart 1961 Price 54 DM

The work deals exclusively with the use of positive contrast media i e the two oily media Lipiodol and Pantopaque and the water soluble medium Abrodil Air myelography is men tioned only incidentally The author in the chapter dealing with congenital malformations states that interest is mainly directed to the anteriorly situated malformations This is evident from a perusal of the chapter dealing with the technique The patient is examined prone on a tilting table This is an integral part of the examination as the lumbar needle when Panto- paque is used has to remain in place during the whole examination in order to facilitate the evacuation of the oily medium Only the anterior aspect of the spinal canal can therefore be examined by this method the posterior part where a great many of the meningoceles are located lying outside its scope

The greater part of the thoracic spinal canal and spinal cord constitute a terra incognitum to the author This is due to the fact that the Lipiodol as well as the Pantopaque are broken up into droplets in the thoracic spinal canal so that this region cannot be investigated It is significant that the author does not discuss the spinal cord in this region except to mention its displacement adjacent to an expansive process It is astonishing in a modern radiologic work, to find a method described that does not allow of an anatomical investigation of the structures involved The author has used Lipiodol as a contrast medium in 75 of all the tumour cases It is stated that the technique and aim of this method are to demonstrate a free passage of the contrast medium from the suboccipital cistern down to the sacral region of the subarachnoid space In sharp contrast to this limited applicability and modest issue are the harmful con sequences to the patient if the medium is not entirely withdrawn after the examination is completed Only when there is complete obstruction to the passage of the Lipiodol will the method produce a reliable result

The water soluble contrast medium Abrodil is used for the examination of the lumbar spinal canal The technique mainly worked out by Swedish investigators is satisfactorily described as are the pathologic changes in the subarachnoid space due to herniated disks which are the main indications for this method

The reviewer is however more convinced than ever after reading this book of the superi ority of a negative contrast medium over oily contrast media in the examination of the spinal subarachnoid space and its content the spinal cord

The book is easy to read and profusely and excellently illustrated More than three hundred references seem to cover all articles of value dealing with positive contrast myelography

Bent Liliequist

PHLEBOGRAPHY AND VENOUS PRESSURE DETERMINATION By M N VAN DER HEYDE 83 pages 23 illustrations H E Stenfert Kroese N V Leiden 1961 Price 5 dollars

The author is a surgeon and the monograph deals with the correlation of the results obtained by phlebography of the leg and venous pressure determinations Phlebography was carried out by the author himself and the films interpreted after consultation with a radiologist. The phlebograms reproduced as an appendix of the book are of good quality Only frontal projec tions were used and the exposures of these were made during fluoroscopy A pair of stereo- scopic films were in each case obtained of the lower leg in order to afford spatial demonstration

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ACTA RADIOLOGICA

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RENAL FUNCTION JUDGED WITH RADIOACTIVE DIODRAST AFTER SELECTIVE RENAL ANGIOGRAPHY IN DOGS

by

B Bodforss T Muth and T Olin

Abdominal aortography and selective renal angiography have now assumed the rank of routine examinations at most radiologic centres The contrast media most widely used e g Urografin and Hypaque belong to the diatrizoate group In Lund we have used Urografin 60 % during the last 8 years for selective renal angiography This explains that the design of the present experimental investigation was to ascertain how large a dose of this medium could be given without producing functional or morphologic renal changes Other contrast media were included in the study for the sake of completeness

Urografin (Schering) 60 % and 76 % consists of a mixture of 10 parts of the sodium salt and 66 parts of the methylglucamine salt of diatrizoate (3 5 di acetaminol 2 4 6 triiodobenzoic acid) and is also sold under the name of Renografin (Squibb) or Radioselectan (Cruet) Hypaque (Winthrop) 25 45 and 50 % is the sodium salt of diatrizoate while Hypaque M 90 % is a mixture of 1 part of the sodium salt and 2 parts of the methylglucamine salt Cardiografin (Squibb) 85 % is a methylglucamine salt

From the Radiation Physics Department and the Roentgendiagnostic Department of the University Hospital and the Institute of Physiology the University of Lund Sweden A preliminary report of this work was presented at the Meeting of the Nordic Medical Radiology Societies Lund Jun 1961 Submitted for publication 14 January 1963

of the state of the veins The phlebography part of the book must nevertheless be looked upon as somewhat amateurish, for example in Fig 5 the deep veins which appear to be supplied with numerous valves are stated to be valveless and in Fig 6 a muscle vein is described as having an abnormal course, when in fact it is varicose The part dealing with venous pressure determinations is clear and instructive The findings described are the recognized ones with a normal pressure fall on muscle activity and more or less impairment of function in cases with pathologic changes Venous pressure determinations were made in 100 legs and were followed by phlebography performed in the semi erect position with injection of the contrast medium through the same cannulation of a foot vein Retrograde phlebography was carried out after venesection and catheterization of the long saphenous vein this examination was also made in the erect position and with the patient straining down in order to evaluate the state of the proximal veins of the leg A classification of the legs into 8 groups was based on the findings at phlebography and depended on the extent and localization of the changes Correlation between the results of the venous pressure readings and this grouping was then attempted Such a classification would obviously not have been possible from pressure readings alone and phlebography was therefore found essential in determining the nature of the impairment of the venous return As to the function of the leg veins the venous pressure determinations appeared to provide more accurate and objective information and could be given in figures Good correlation was found to exist between the methods Venous pressure determination can hardly ever serve, however in clinical practice as a substitute for phlebography although it may often be employed as a complement to the latter This is exemplified by the statement that venous pressure determination does not enable any differentiation to be made between an obliterated and an incompetent popliteal vein

The subject of the work is well covered and the analysis of the methods is presented with care The conclusions would appear to be based upon principles that are sound and ones that should be adopted more generally in phlebography The book is in fact stimulating and readable and should provide a better understanding of the problems of the venous return of the leg

Åke Gullmo

RADIOGRAPHIC ATLAS OF SKELETAL DEVELOPMENT OF THE FOOT AND ANKLE *A standard of reference* By Normand L Hoerr S Idell Pyle and Carl C Francis 163 pages 50 illustrations and 11 tables Charles C Thomas Springfield Ill 1962 Price 9 50 dollars

This book the third in a planned series of six is an extensive and detailed study of the skeletal development of the foot and ankle of normal infants and children It is based on serial roentgenograms of about 1 000 subjects taken at three six or twelve month intervals from birth to the age of eighteen years

The work is divided into three parts In the first part a detailed description is given of the method of constructing the standard The second part the standard of reference is the major section of the atlas and consists of thirty plates which make it possible to assess the skeletal age and the maturation by means of a single roentgenogram The third part contains numerous drawings schematically showing typical roentgenographic outlines of the bones at particular stages of their development The book ends with an appendix consisting of tables giving the times of appearance of the centres of ossification throughout the body including means and standard deviations

The numerous and excellent illustrations and the good descriptive text renders this a most useful radiographic atlas

Kjell Bergstrom

The renal damage liable to occur in association with selective renal angiography may be due to the actual catheterization procedure, or the injection of contrast medium or to both. LINDELL & OLIN (1957) considered that the presence of a catheter in one of the renal arteries in 2 dogs had no influence on the renal blood flow. The presence of a catheter in one of the renal arteries also appeared to have no effect on the phenol red clearance in 2 dogs and in 1 cat, but in another cat in which the catheter had been passed too far into the renal artery, spasm developed around the catheter and the production of urine on the catheterized side fell markedly. The catheter was withdrawn a little and the spasm disappeared but even 3 hours later the clearance on the side catheterized was still reduced to about 30 % of normal.

HELANDER (1958) described an investigation in dogs of the effect of catheterization of the renal artery on the clearance of inulin and para aminohippuric acid (PAH) and on the extraction of PAH. The spread of the clearance values in his investigation was very wide and therefore warrant no valid conclusions. The presence of the catheter generally produced no influence on renal function but occasionally function was reduced on the catheterized side, on the other side or on both sides.

Evaluation of the effect (functional and anatomical) of the contrast medium on the kidney in association with arteriography requires knowledge of the concentration of the contrast medium in the actual renal artery, the amount of contrast medium supplied to the kidney and the application time. The significance of the latter has been stressed by BROMAN & OLLE OLSSON (1948) in their investigation of the effect of contrast medium on the blood brain barrier. It would, however, appear that this factor has not been considered in previous investigations of renal function. Thus in IDBOHRN & BERG's investigation in rabbits in 1954, the application time was varied between at least 10 to 20 seconds and the amount of contrast medium by 0.3 to 1.5 ml without these variations being included in the tables of the renal injuries. This probably explains why they found the tolerance of the kidney to contrast medium to vary so widely with its concentration. These authors in a later investigation in 1958 used a standard application time of 10 seconds and a standard volume of contrast medium of 1 ml irrespective of the size of the animal. The variations of renal damage with the concentration of the contrast medium was much narrower in that investigation and the authors concluded that renal damage following injection of sodium acetrizoate varied with the concentration of the contrast medium. Diatrizoate compounds (Hypaque M 90 % and Urografin 76 %) caused no damage. The findings of BERG, IDBOHRN & WENDEBERG (1958) concerning the toxicity of various contrast media in rabbits are of considerable value but add no knowledge regarding injuries occurring in association with renal angiography in living subjects in which the renal artery is not occluded during the injection of contrast medium.

HELANDER (1958) injected contrast medium selectively into the renal artery

WINZER, LANGECKER & JUNKMANN (1954) studied the tissue respiration of rat liver sections in a Warburg apparatus before and after the addition of various contrast media. They reported that sodium diatrizoate caused the least inhibition of respiration. They also found diatrizoate given intravenously to be the least toxic of all known contrast media. The LD 50 of this medium in rats was 14.7 g/kg bodyweight.

HOPPE (1959) studied different contrast media for their injurious effect on the blood brain barrier, using the method of BROMAN & OLLE OLSSON (1948), and reported the diatrizoate preparations to be the least toxic. KILLEN, LANCE & OWENS (1959) examined the spinal cord after the injection of sodium acetrizoate 70 % (Urokon, Mallinckrodt) and diatrizoate 90 % (Hypaque M 90 %) into the lumbar aorta and demonstrated that diatrizoate had only a slight toxic effect in this area.

The nephrotoxic effect of contrast medium injected into the renal artery was investigated by BERG, IDBOHRN & WENDEBERG (1958). These authors injected 1 ml contrast medium within 5 to 8 seconds into the renal artery of the rabbit during which the blood supply to the kidney was shut off (10 seconds). The animals were killed 1 hour, 2 hours, 13 hours and 3 days, but mostly 1 hour, after the injection. Subsequent microscopic examination revealed injury after the injection of iodopyracet 17.5 % (Umbradil, Astra), sodium acetrizoate 25 % (Triurol, Leo) and sodium diprotrizoate 50 % (Miokon, Mallinckrodt), while diatrizoate 76 and 90 % (Urografin and Hypaque M, respectively) produced no demonstrable damage.

The histologic appearances of the kidney after injection of contrast medium into the renal artery in the rabbit were described exhaustively by BERG & IDBOHRN (1954). Hyperemia was demonstrable in the glomeruli with albuminous exudate in Bowman's capsule and the convoluted tubules as early as 15 minutes after the injection. The tubules also showed hyaline drop degeneration and the exudate in the tubules tended to develop into hyaline, eosinophilic casts. In animals killed 1 hour after the injection the epithelial cells in the distal tubules became flatter and some of them were shed so that more granular casts formed and the cell nuclei displayed pyknosis. Most of the changes described regressed considerably within 24 hours but the epithelial necrotic foci persisted longer. Marked regeneration appeared after 2 to 4 days, and after 3 days only insignificant changes were demonstrable.

KILLEN & LANCE (1960) injected 15 ml contrast medium into the aorta of the dog at the level of the origins of the renal arteries and then studied the serum NPN. Diatrizoate 90 % (Hypaque M) and sodium diprotrizoate 90 % (Miokon) produced no change in the NPN although an alteration was noted after the injection of other contrast media, namely sodium acetrizoate 70 % (Urokon), sodium iodomethamat 75 % (Neo Iopax) and iodopyracet 70 % (Diodrast).

Extensive clinical experience also suggests that diatrizoate compounds are the best contrast media now available (ABRAMS 1961).

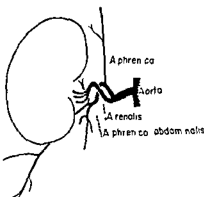


Fig 1 Anomaly observed in 2 of 16 dogs The renal artery has a common trunk with the phren co-abdominal and phrenic arteries

of dogs usually at an injection rate of about 5 ml/sec This rate of injection is probably sometimes higher than the rate of flow through the kidney This author in some of his studies of the nephrographic effect injected the contrast medium at a rate of only 1 2 ml/sec probably somewhat less than the rate of the renal blood flow This relatively slow injection rate in at least one of his experiments (pages 24—27, Fig 10) may have been sufficient by reason of the presence of a clot at the bifurcation of the right renal artery visible in the figure but obviously disregarded by him In his examination of renal injury following selective renal angiography this author injected 5 to 30 ml of sodium diprotrizoate 50 % (Miokon) 3 to 10 ml of iodopyracet 50 % (Umbradil) and 5 + 5 ml of sodium acetrizoate 40 % (Rheopak) and took serial roentgenograms He found no distinct correlation between the dose and the concentration, on one hand and the severity of renal injury on the other All the cases in his paper in which the application time (= the time the arteries were filled with contrast medium) could be assessed with some degree of certainty, and in which histology is mentioned are given in Table 1

It will be seen from this Table that renal injury depends on four factors the application time and the type dose and concentration of the contrast medium Only in one animal F 17 were deviating values obtained, and they may have been due to an anatomic variant (see Fig 1) The application time in renal angiography performed lege artis varies with the amount of contrast medium injected This type of investigation aims at transiently replacing the blood in the renal artery by contrast medium The rate of injection should be properly adjusted neither too high for then the contrast medium will flow back into the aorta nor too low, for then the concentration of the contrast medium in the renal artery will fall Since the rate of flow of blood through the kidney may vary during angiography, owing to the effect of the injection of contrast medium on the blood vessels, heart renal parenchyma and blood the contrast medium should be injected under fluoroscopic control The rate of

Table 1

Based on HELANDER'S *investigations (1958) of the nephrotoxicity after injection of contrast media directly into the renal artery — only those cases are included in which the application time is stated or can be estimated and in which the histology is mentioned*

Contrast media	Dog No	Dog Kg	Doses of contrast media: Side	Total dose (ml)	mg/kg body weight	Application time (sec) (approx)	Histology: Glomeruli	Histology: Tubules	Function test	Time interval between angiography and kidney examination (days)
Diprotrizoate (Na diprotrizoate) *Miokon sodium*										
30 %	F 271	27 5	R	5	55	1	N	N		4
			L	5	55	1	N	+		
	F 50	2? 8	?	5	65	1	N	N	N	?5
	F 51	20 2	R	5	75	1	N	N	N	?5
			L	5	75	1	N	N	N	
	F 36	20 [illegible]	R	5	75	1	N	N	N?	33
	I 266	20 0	R	5	75	1	N	N		19
			L	5	75	1	N	N		
	F 274	20 1	R	5	75	1	N	(+)		5
			L	5	75	1	N	(+)		
	F 40	17 9	?	[illegible]	85	1	N	N	N	25
[illegible]0	F 187	15 1	?R	12	400	3	+	+		60
	F 196	24 3	?R	30	620	7+4	+ + +	+ + +		[illegible]6
	I 227	?2 0	?R	30	680	7	+ + +	+ + +		4[illegible]
	[1]F 20	21 8	?R	30	690	7+35	+ + +	+ + +	+ + +	4
	F 13	20 6	?R	30	730	7+ 7	+(+)	+(+)	+	4
	F 17	20 ?	?R	30	740	7	N	N	N	4
	[1]F 44	19 2	?R	30	780	7+35	+ + +	+ + +		4
	F 25	17 7	?R	30	850	7	+ + +	+ + +	+ + +	4
Iodopyracet *Uribradil*										
35 %	F [illegible]	19 0	?	3	55	1	N	N		17
50 %	F [illegible]	19 0	?	4	1 050	1	N	(+)		4
	F 19	21 [illegible]	R	8	1 860	1 6	+ + (+)	+ + (+)		5
			L	8	1 860	1 6	+	N		
	F 6	18 5	?	10	2 700	?	+ + + +	+ + + +		1?0
Acetrizoate (Na acetrizoate) *Rheopak* 40	[2]F 10	25 0	?	[illegible]+5	1 600	?	+ + + +	+ + + +		120

[1] Partial occlusion of renal artery [2] Complete occlusion of renal artery

Table 2

Renal function and histology after selective renal angiography with diatrizoate and acetrizoate 0 = No signs of damage by media + and ++ Protein in and dilatation of the tubules +++ and ++++ Protein in and dilatation of the tubules as well as epithelial necrosis

Contrast media	Dog No and Sex		Dog Kg	Doses of contrast media: Total dose (ml)	mg/kg body weight	Application time (sec) (approx)	Extraction ( ) of diodrast from blood before and after renal angiography: Before	After	Difference	Time interval between angiography and function test (days)	Histology
Diatrizoate Na salt & methyl glucamine salt 10 6[illegible]) Urografin											
60	5	♀	6 5	1 3	1 [illegible] 0	<1	58	60	+ 2	5	0
	8	♂	9	5	330	1	46	50	+ 4	1	0
	7	♀	10.5	6	360	1	44	43	− 1	10	0
	13	♀	23	40	1 040	65	56	57	+ 1	1	0 No typical contrast damage but small nonspecific changes
				110	2 860	150	57	55	− 2	1	0
	25	♂	17	50	1 760	40	60	54	− 6	1	(+) Discrete changes
76	23	♂	17	17	760	12	54	35	−19	1	0 Fresh infarction
	22	♂	13	20	1 170	14	42	36	− 6	1	0
	21	♀	9 5	40	2 900	75	61	45	−16	1	+
	19	♂	9 5	40	2 [illegible]00	50	49	0	−49	1	++++
Na salt & methyl glucamine salt 1 2)											
Hypaque M 90	1	♂	23	7 5	290	10	50	42	− 8	1	+
	24	♂	25	15	540	18	50	36	−14	1	++
Acetrizoate (Na acetrizoate)											
Triurol [illegible]0	15[4]	♀	11	<5	<310	1	49	37	−12	1	+
	16	♀	17	5	200	1	50	19	−31	1	+++
	14	♀	12 5	18	1 000	15	37	–	–	0	Intense hyperemia protein in tubules, some interstitial oedema

Numbered footnotes see opposite page

injection may then be modified, if necessary, in roughly the same way as BROMAN & OLLE OLSSON (1948) adjusted the application time in the brain by inspection through a hole trephined in the skull If the contrast medium is injected under fluoroscopic control the application time should vary with the amount of contrast medium injected

General principle Renal function was studied both before and after selective injection of contrast medium into the renal artery Renal function was judged from the power of the kidneys to extract radioactive diodrast by the method described by BODFORSS, MUTH & OLIN (1964) The kidneys were examined microscopically after the last functional test

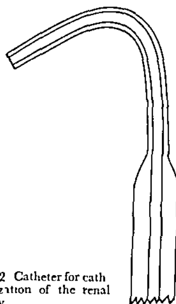


Fig 2 Catheter for catheterization of the renal artery

Method of estimating renal function Twenty dogs were used The animals were anesthetized with about 30 mg/kg bodyweight pentobarbital sodium, U S P (Mebumalnatrium 6 %, ACO) intravenously Superficial anesthesia was maintained by small supplementary doses of the anesthetic intravenously The dogs during preparation were placed on the back and during the actual experiment on one side The animals were given heparin (2 to 2 5 mg/kg body weight) The rectal temperature was continuously measured and kept constant during the test Shorthaired dogs often required extra warming with a lamp The animals, which had been deprived of food for 12 hours before the experiment, were given 200 to 600 ml of 5 5 % glucose, slowly intravenously The blood pressure during the experiment was measured continuously with a mercury manometer connected to a polythene catheter inserted into an artery Blood samples were collected for hematocrit determination by a micromethod The right renal vein was catheterized in the way previously described (BODFORSS, MUTH & OLIN 1964)

A dose of diodrast ^{131}I was injected intravenously after which the concentration of the substance was measured alternately in the aortic and renal venous blood Selective renal angiography was performed after the measurements had been made

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[1] The interval between the two injections was one day and both were made into the right renal artery
[2] Catheter in renal artery for two hours [3] Renal artery intentionally blocked for 5 min before and during injection [4] 5 ml injected but most of the dose was extrarenal via the anomalous artery (Fig 1)
[5] Died in convulsions about 10 min after injection

Care was taken in the preparation of the animals to keep all manipulations as identical as possible before and after angiography in order to reduce or avoid sources of error that might have been introduced by differences in the examination technique

Discussion

A good correlation was found between the amount concentration and application time of the contrast medium injected on one hand and the effect of the injection on the function and morphology of the kidney on the other

The deviating values could be explained by technical complications in farction by emboli (No 23), anomalies of the renal blood supply (No 15), and intentional occlusion of the renal artery (No 19) The deviating value in No 25 could probably be explained by the fact that the catheter had been in the renal artery for two hours before the test The catheter probably impaired the renal blood supply because although the animal was anesthetized it probably moved while being transported to another department It is also clear from the table that sodium acetrizoate (Triurol) in a dose of 200 mg/kg bodyweight which does not appear excessive from a clinical viewpoint, produces functional and morphologic changes in the kidney 24 hours after angiography (No 16) The concentration of the contrast medium was however fairly high (70 %)

As to the diatrizoate compounds in concentrated form (Hypaque M 90 %), these are more injurious than those of lower concentration (Urografin 76 and 60 % respectively) in equal doses Neither diatrizoate 76 % nor 60 % in clinically reasonable doses (up to 200 mg/kg bodyweight), had any demonstrable toxic effect on the kidney The smallest dose of the 76 % solution tried 760 mg/kg bodyweight is thus 3 to 4 times as large as the conventional clinical dose used for selective renal angiography but produced no demonstrable injury As to the 60 % solution this was given in doses about 15 times as large as clinically reasonable doses without giving rise to any damage ascribable to the contrast medium A corresponding volume of 76 % solution 2 900 mg/kg body weight however produced moderate functional and morphologic damage

The injurious effect of having the tip of the catheter in a wrong position is obvious from dog No 19 in which the renal artery was intentionally occluded for about 5 minutes with a catheter before and during injection of the contrast medium diatrizoate 76 % The tip of the catheter was withdrawn into the aorta at the end of the injection The following day renal function tests showed a silent kidney and severe macroscopic and microscopic morphologic changes With the same method and same volume of contrast medium injected into an unoccluded artery only moderate lesions (No 21) were produced The dose of contrast medium was large namely 2 900 mg/kg bodyweight in both cases

The histologic changes increased in severity with reduction in the power of extraction of diodrast When this was reduced by more than 6 units (1 unit = 1 per cent extraction) histologic renal changes could invariably be demonstrated

Technique used for selective renal angiography Thin radiolucent, polythene tubing (O D /I D = 0 97/0 58 mm, PL 50) with gold markers in the tip (LINDELL & OLIN 1957) was used for catheterization of the renal artery in small dogs, and in large animals, radiopaque, polythene tubes (Kifa, Ö L No 1 red, O D /I D – 2 2/1 2 mm) were used

A part of the catheter containing a guide wire is cold drawn by a sharp pull, which considerably decreases the outer diameter of the tube, while the guide wire prevents the inner diameter from decreasing The cold drawn part of the catheter is then warmed and curved to facilitate introduction into the renal artery (Fig 2) The use of this special catheter reduces the risk of impairing the flow of blood through the kidney during catheterization

The catheter was passsed about 1 cm into the right renal artery The contrast medium was injected manually, and under fluoroscopic control, so that the rate of injection could be adjusted according to the flow in the renal artery If the rate of injection relative to that of the blood in the renal artery is too low, the concentration of the contrast medium in the vessel will fall, and if the contrast medium is injected at too high a rate, it will regurgitate into the aorta An anatomic variant, consisting of a large vessel extending from the renal artery about 1 5 cm from the aorta, was observed in 2 of 16 dogs This wide branch was found to consist of a common trunk of the phrenic artery and the phrenico abdominal artery (a lumbo abdominalis or a lumbalis superficialis, FRANK) (Fig 1) This variant has been described by FILEXBERGER & BAUM (1891) but appears to have passed unnoticed by later investigators If, in animals with this anomaly, the tip of the catheter is not situated in the actual renal artery, part of the injected contrast medium will enter the common trunk of the phrenic artery and the phrenico abdominal artery, and an unknown amount will enter the kidney The application time, which is defined as the time the renal artery is filled with contrast medium, and the amount and concentration of the contrast medium used, were noted on selective injection of the contrast medium into the renal artery Films were sometimes exposed during the actual injection of the contrast medium in order to appraise the cross sectional area of the renal artery occupied by the catheter Measurements of the outer diameter of the catheter, and the inner diameter of the contrast filled renal artery at the same site, were made in these films About 6 to 8 %, of the inner cross section of the artery was found to be occupied by the catheter In one case (H 19) the renal artery was intentionally occluded with a thick catheter

One day after angiography renal function was again assessed by the method described The interval between angiography and subsequent renal function tests in a few cases was several days (see Table 2) The animals were killed and the kidneys removed for histologic examination after the renal function tests had been completed

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The renal artery and arteries running to the diaphragm and abdominal muscles stem in some dogs form a common trunk This observation should be borne in mind in selective deposition of contrast medium in the renal artery because in such cases part of the contrast medium will be deposited extrarenally This normal variant appears not to have been considered in investigations by previous workers on the effect of contrast medium on the kidneys

Acknowledgements

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SUMMARY

Renal function as judged by the power of the kidney to extract diodrast from the blood was studied before and after selective renal angiography in dogs The histologic changes increased in severity with the reduction in the power of extraction the damage varying with the type and dose of the medium its concentration within the renal artery and the application time Diatrizoate 60 % was found to be the best medium available for selective renal angiography

ZUSAMMENFASSUNG

Die Funktionstuchtigkeit der Niere ausgedruckt durch deren Fahigkeit Diodrast aus dem Blut zu entfernen wurde vor und nach selektiver Angiographie an Hunden untersucht Die histologisch sichtbaren Veranderungen verstarkten sich in ihrer Schwere mit der Abnahme der Funktionstuchtigkeit der Schaden ist abhangig von der Art und Dose der Konstrast substanz von deren Konzentration in der Nierenarterie und von deren Durchlaufzeit Diatrizoat 60 % erwies sich als das beste verfugbare Mittel zur selektiven Nierenangiographie

RÉSUMÉ

La fonction rénale évaluée par l aptitude du rein à extraire le diodrast du sang a été étudiée avant et après angiographie rénale sélective sur des chiens La gravité des lésions histologiques augmente avec la réduction du pouvoir d extraction selon le type et la dose du moyen de contraste utilisé selon sa concentration dans l artère rénale et la durée d administration C est le diatrizoate à 60 % qui s est montré le meilleur moyen de contraste pour l angiographie rénale sélective

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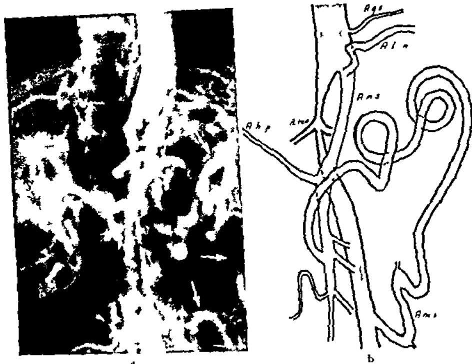


Fig 1 Case 1 Coarctation at renal artery level a) Abnormal origins of left gastric splenic and hepatic arteries The medium passes from the superior mesenteric artery through a long tortuous collateral (arrow) to the inferior mesenteric artery b) Schematic representation of several films from the beginning and end of the series A g s — left gastric artery A lien — splenic artery A hep — hepatic artery A ren — renal artery A m s — superior mesenteric artery A m i — inferior mesenteric artery

Case reports

Case 1 Male aged 25 normally developed with no history of abdominal surgery or obscure abdominal pain Hypertension discovered incidentally of 165/100 Weak femoral pulse palpable bilaterally A murmur was present over the left of the lumbar spine Pressure measurements in the aorta revealed a systolic gradient at the level of the renal arteries

Roentgenologic findings (Fig 1) The lumen of the abdominal aorta was reduced to half of its normal diameter over a distance of 7 to 8 cm The renal arteries had a common origin in the ventral portion of the stenosed area The celiac trunk was absent the splenic and the left gastric arteries arose from the proximal portion of the superior mesenteric artery as did the hepatic artery although approximately 7 cm distally A further 4 cm lower down the contrast medium entered a dilated collateral vessel which after a very tortuous course in the left side of the abdomen opened into the inferior mesenteric artery

Case 2 Male aged 44 with a 20-year history of gastric ulcer otherwise healthy Blood pressure 130/85 Gastric resection type Billroth II had been performed four years previously for duodenal ulcer the immediate postoperative course being uneventful except for mild diarrhea Ten days after the operation intense abdominal pain was followed by collapse Since the underlying cause was obscure aortography was performed four weeks after the gastric resection

FROM ROENTGEN DEPARTMENT I (DIRECTOR PROF S R KJELLBERG), SAHLGRENSKA SJUKHUSET, GOTHENBURG, SWEDEN

ABNORMAL COMMUNICATIONS BETWEEN SPLANCHNIC VESSELS

by

I Brolin and S Paulin

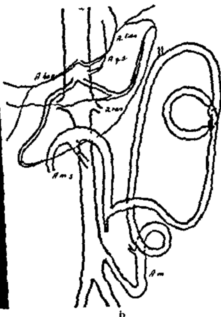
An abnormal distribution of the branches of the abdominal aorta was observed in three angiograms in cases of hypertension in 1961 and 1962 These observations prompted a revaluation of the angiographic findings in 810 abdominal aortographies carried out between June 1958 and February 1962 in our department and resulted in the discovery of two additional cases with anomalous arterial distribution resembling those previously noted The histories and clinical and angiographic findings in these five cases were therefore examined and reviewed in the hope of elucidating the nature and significance of these vascular abnormalities

Methods and Material The contrast medium in these five cases was injected through a catheter introduced percutaneously via a femoral artery, the tip being placed approximately at the level of the renal arteries Forty to 60 ml of contrast medium were injected with the aid of an automatic injector (Gidlund) over a period of 2 to 3 seconds Exposures were made for a period of 20 seconds with an Elema roll film or cut film changer In Case 1 biplane films were obtained while in the remaining cases stereoscopic views were obtained in the frontal plane for a period of 20 seconds The patients consisted of one female and four males of ages ranging from 25 to 52

Submitted for publication 25 February 1963



a



b



c

Fig 3 Case 3 Arteriosclerotic constri t on of the superior mesenteric artery a) Abnormally narrow caliber of the celiac artery and its branches d lated collateral (arrow) from the inferior mesenteric artery the contrast medium has not yet entered the superior mesenteric artery b) Schematic representation (abbreviations as in fig 1b) c) Dilated tortuous vessels at the s te of the suprarenal arter es

Case 4 Male aged 52 with a history of bilateral renal colic from 1936 to 1942 with pyeloli thotomy for right nephrolithia is in the latter year The postoperative course was uneventful apart from mild pa n in the right lower quadrant for which appendectomy was performed He subsequently remained asymptomatic until 1961 when he had a brief attack of dizziness Examination d sclosed hypertension the blood pressure being 170/120 (in 1936 135/85) The femoral artery pulses were normal

Roentgenologic f ndi gs (Fig 4) The aorta was of normal caliber throughout The medium entered a tortuous collateral from the inferior mesenteric artery which was dilated The collateral ran to the left upper portion of the abdomen then turned almost 180 degrees and descen led into the right lower quadrant The vessel in its proximal part gave off a few small branches to the sigmoid and the descending colon in the right lower quadrant of the abdomen t turned sharply and approximately in the midline at the level of L 3 divided into branches identifiable as the left gastric the splenic and hepatic arteries and vessels corresponding to branches of the superior mesenteric artery supplying the small intestine Neither the initial nor

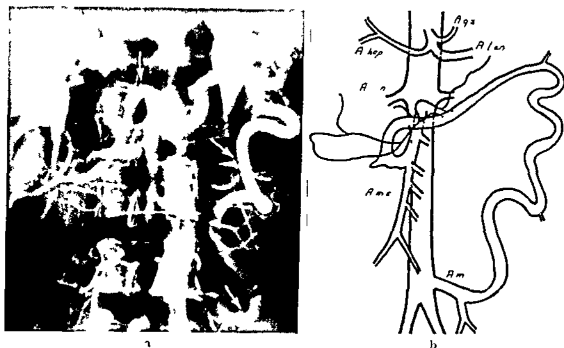


Fig 2 Case 2 Thrombosis of the superior mesenteric artery a) Film from end of series Filling of the superior mesenteric artery via a tortuous collateral (arrow) from the inferior mesenteric artery b) Schematic representation (abbreviations as in fig 1b)

Roentgenologic findings (Fig 2) The aorta showed no abnormal variations in size The contrast medium passed from the inferior mesenteric artery into a dilated vessel that extended cranially to the left then transversely and after a tortuous course in the right of the abdomen terminated in the superior mesenteric artery Contrast filling of the latter artery was first established via the collateral vessel during the late phase of the examination and its proximal portion presented evidence of retrograde filling The celiac artery was filled directly from the aorta and appeared normal No collaterals were observed between the celiac and superior mesenteric arteries

Case 3 Female aged 49 operated on for right ovarian cyst in 1941 and 1943 hysterectomy in 1959 for myoma The postoperative course on each occasion was uneventful Hypertension was observed in connection with the hysterectomy and in 1962 the blood pressure was 215/120 Murmurs were present over the left side of the abdomen the femoral artery pulses were normal

Roentgenologic findings (Fig 3) Although no variations in the caliber of the aorta were evident the vessel had a somewhat tortuous course with small irregularities of the wall A dilated vessel extended from the inferior mesenteric artery in a very similar way to the vessel in Case 2 The celiac artery arose at the normal site but together with its major branches was abnormally narrow There was no detectable flow of contrast medium from the aorta directly into the proximal portion of the superior mesenteric artery Caudal to the celiac artery a few fairly large vessels — probably the pancreatico duodenal and gastro epiploic arteries — received a small amount of medium The tortuous collateral exhibited two short strictures in the left side of the abdomen at the level of L 2 The renal arteries appeared normal Small dilated and tortuous vessels were descernible at the sites of the suprarenal arteries (Fig 3c)

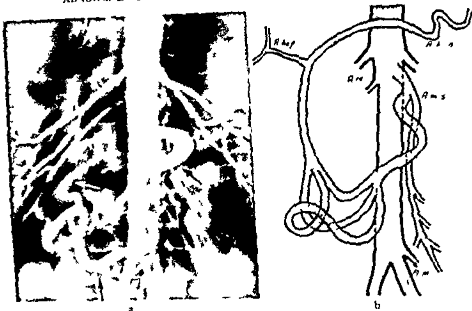


Fig 5 Case 5 a) Dilated tortuous collaterals (arrow) from the superior mesenteric artery to branches of the celiac artery b) Schematic representation (abbreviations as in fig 1)

in length was present in the wall of the collateral A thrill was palpable distal to the stricture The superior mesenteric artery in its proximal part was markedly sclerosed and had only a minimal blood flow The arteriosclerotic lesions continued into the aortic wall It was not possible to inspect the origin of the celiac artery Common to these five cases (Fig 6) was the fact that one or more of the normally occurring anastomoses between the unpaired splanchnic vessels had developed into a tortuous dilated collateral In the first case this dilated vessel was an integral part of the collateral system that had formed between the cranial and caudal sections of the aorta as a result of an abdominal coarctation In the second case the circulation, following thrombosis of the proximal superior mesenteric artery, was taken over by the inferior mesenteric artery from which a collateral to the peripheral segments of the former artery developed The abnormal vascularization in the third case was similar to that in Case 2 but differed clinically from the latter in the absence of a clinical history of thrombosis or other vascular disease The occlusion of the superior mesenteric artery in Case 3 was probably due to gradually progressive arteriosclerosis

There was nothing in the histories of the remaining two unoperated cases to suggest vascular involvement Case 4 had a collateral similar to that in Case 3 though it supplied not only the superior mesenteric region but that of the celiac artery as well In the fifth case a vascular communication existed between branches of the superior mesenteric and the celiac arteries

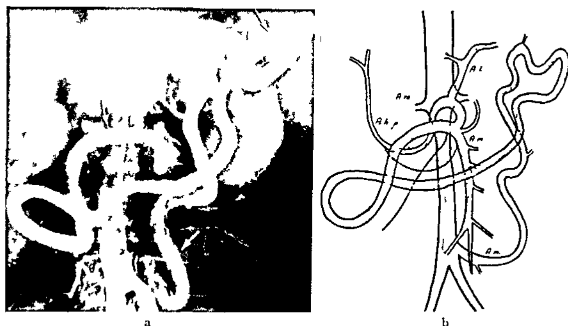


Fig 4 Case 4 a) Branches of both the celiac and the superior mesenteric arteries receive contrast medium via the long tortuous collateral artery (arrow) from the inferior mesenteric artery b) Schematic representation (abbreviations as in fig 1b)

the subsequent angiograms in the series revealed any contrast filling of a normal celiac artery or the proximal part of the superior mesenteric artery The renal arteries appeared normal Small dilated vessels were discernible cranial to the renal arteries in this case as well

Case 5 Male aged 48 with mitral disease following rheumatic heart disase at 19 No clinical evidence of embolism The patient underwent cholecystectomy in 1954 with an uneventful postoperative course No periodic abdominal pain of obscure etiologic origin He was investigated for hyperten ion in 1961 when the blood pressure was 180/130

Roentgenologic findings (Fig 5) The aortic caliber was normal and showed no variations The superior mesenteric artery gave off three fairly large tortuous vessels which after running about 7 to 8 cm joined to form a single trunk this ran a distance of 5 cm then ramified into vessels corresponding to the hepatic and splenic arteries There was no appreciable contrast filling of the celiac axis The inferior mesenteric and the renal arteries appeared normal

The angiographic findings were operatively verified in 3 of these 5 cases Case 1 was subjected to implantation of a patch graft into the abdominal aorta (Ekestrom and Hansson) The aortic wall was of normal consistency and the intima had no atheromatous or arteriosclerotic changes At exploratory laparotomy (Bergfeldt) in Case 2 the roentgenologically observed collateral from the inferior mesenteric artery was readily identifiable and its temporary occlusion resulted in the immediate cessation of pulsations in the arteries of the mesentery and the proximal part of the small intestine These areas therefore received their blood supply from the inferior mesenteric artery The superior mesenteric artery was totally occluded by a thrombus

At operation on Case 3 (Hansson) an arteriosclerotic thickening, about 5 mm

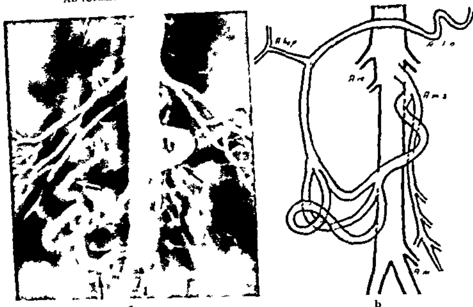


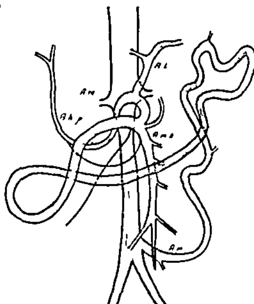
Fig 5 Case 5 a) Dilated tortuous collaterals (arrow) from the superior mesenteric artery to branches of the celiac artery b) Schematic representation (abbreviations as in fig 1b)

in length was present in the wall of the collateral A thrill was palpable distal to the stricture The superior mesenteric artery in its proximal part was markedly sclerosed and had only a minimal blood flow The arteriosclerotic lesions continued into the aortic wall It was not possible to inspect the origin of the celiac artery Common to these five cases (Fig 6) was the fact that one or more of the normally occurring anastomoses between the unpaired splanchnic vessels had developed into a tortuous dilated collateral In the first case this dilated vessel was an integral part of the collateral system that had formed between the cranial and caudal sections of the aorta as a result of an abdominal coarctation In the second case the circulation following thrombosis of the proximal superior mesenteric artery, was taken over by the inferior mesenteric artery from which a collateral to the peripheral segments of the former artery developed The abnormal vascularization in the third case was similar to that in Case 2 but differed clinically from the latter in the absence of a clinical history of thrombosis or other vascular disease The occlusion of the superior mesenteric artery in Case 3 was probably due to gradually progressive arteriosclerosis

There was nothing in the histories of the remaining two unoperated cases to suggest vascular involvement Case 4 had a collateral similar to that in Case 3 though it supplied not only the superior mesenteric region but that of the celiac artery as well In the fifth case a vascular communication existed between branches of the superior mesenteric and the celiac arteries



a



b

Fig 4 Case 4 a) Branches of both the celiac and the superior mesenteric arteries receive contrast medium via the long tortuous collateral artery (arrow) from the inferior mesenteric artery b) Schematic representation (abbreviations as in fig 1b)

the subsequent angiograms in the series revealed any contrast filling of a normal celiac artery or the proximal part of the superior mesenteric artery The renal arteries appeared normal Small dilated vessels were discernible cranial to the renal arteries in this case as well

Case 5 Male aged 48 with mitral disease following rheumatic heart disase at 19 No clinical evidence of embolism The patient underwent cholecystectomy in 1954 with an uneventful postoperative course No periodic abdominal pain of obscure etiologic origin He was investigated for hypertension in 1961 when the blood pressure was 180/130

Roentgenologic findings (Fig 5) The aortic caliber was normal and showed no variations The superior mesenteric artery gave off three fairly large tortuous vessels which after running about 7 to 8 cm joined to form a single trunk this ran a distance of 5 cm then ramified into vessels corresponding to the hepatic and splenic arteries There was no appreciable contrast filling of the celiac axis The inferior mesenteric and the renal arteries appeared normal

The angiographic findings were operatively verified in 3 of these 5 cases Case 1 was subjected to implantation of a patch graft into the abdominal aorta (Ekestrom and Hansson) The aortic wall was of normal consistency and the intima had no atheromatous or arteriosclerotic changes At exploratory laparotomy (Bergfeldt) in Case 2 the roentgenologically observed collateral from the inferior mesenteric artery was readily identifiable, and its temporary occlusion resulted *in the immediate cessation of pulsations in the arteries of the* mesentery and the proximal part of the small intestine These areas therefore received their blood supply from the inferior mesenteric artery The superior mesenteric artery was totally occluded by a thrombus

At operation on Case 3 (Hansson) an arteriosclerotic thickening, about 5 mm

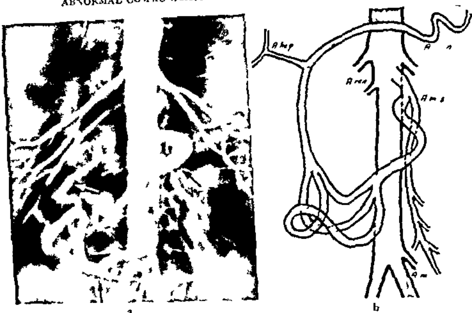


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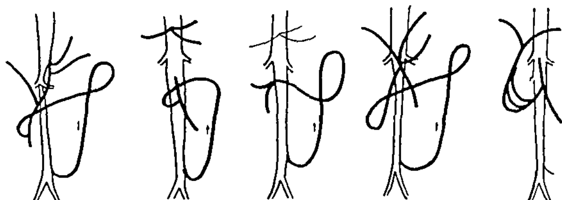


Fig 6 Schematic representation of all five cases with various forms of collateral communications between splanchnic vessels

Discussion

The literature supplies only a few reports of collateral communications between splanchnic vessels BAYLIN (1939) published a case with coarctation of the abdominal aorta, in which autopsy revealed a dilated, tortuous collateral between the superior and inferior mesenteric arteries This collateral consisted of the middle and left colic arteries and the arcades between them It appeared to him that a collateral of this type between the mesenteric vessels was more important than the collateral systems in the abdominal wall ASK UPMARK et coll (1962) recently published a case of abdominal coarctation with a dilated inferior mesenteric artery SENNING et coll (1960) referred to 29 cases of abdominal coarctation and added three personal cases A dilated vessel is discernible in the left side of the abdomen in roentgenograms or specimens from previously reported cases (SENNING, Case 2, DOUMER et coll 1951, EDWARDS 1961) This vessel is analogous with the collateral described by BAYLIN and with the angiographically demonstrated collateral, extending between the superior and inferior mesenteric arteries, in the present Case I

Similar collateral circulations have been reported by FELSON (1954), and by SUTTON (1962), in cases of thrombosis of the abdominal aorta caudal to the origin of the renal arteries The pathologic changes in these cases are due to acquired occlusion of the aorta Abdominal coarctation is unlikely to be due to a single etiologic factor There are cases recorded of marked aortic constriction at renal artery level in which both the gross and the microscopic findings are suggestive of arteritis (DANARAJ et coll 1959) Most authors (ASK UPMARK & LODIN, FISCHER & CORCORAN 1952, SCHWARTZ et coll 1957, FROMENT et coll 1952, HANSSON et coll 1959, KONDO et coll 1950), consider, however the constriction to be congenital The operative findings in the present case — absence of aortic wall lesions with abnormal origins of the hepatic, splenic and left gastric arteries — point to a congenital condition

Three of the present cases had collaterals similar to those associated with coarctation except that the circulation was in the opposite direction The clinical findings in Case 2 suggest that the superior mesenteric artery became rapidly occluded, whereas in Case 3 the occlusion was probably insidious, thus accounting for the absence of acute abdominal symptoms The blood supply to the vascular areas distal to the occlusion was taken over in both instances by the inferior mesenteric artery via the above mentioned collateral vessels the middle and the left colic arteries Neither of these two cases had collateral pathways between the celiac and superior mesenteric arteries This was under standable in Case 2 in which the normal anastomoses between those vessels had been severed at operation In Case 3, the unsatisfactory contrast filling of the narrow celiac artery suggested that this vessel too was the site of arteriosclerotic lesions such as those observed at operation in the superior mesenteric artery and the abdominal aorta The substantial increase in caliber of the inferior mesenteric artery within only four weeks (Case 2) reflects the magnitude of the collateral circulation through that pathway The rapid development of this collateral also accounts for the favorable course and shows that the blood supply to the superior mesenteric region can be taken over entirely by the inferior mesenteric artery

EDWARDS has described four cases of thrombosis of the superior mesenteric artery in elderly subjects in each of which the condition had been ushered in by severe abdominal pain and in each of which it was fatal ROB et coll (1956 1959) on the other hand have reported occlusion of both the celiac and the superior mesenteric arteries without clinically alarming symptoms The pa tient was a 35 year old man with a syphilitic aneurysm of the thoracic aorta Operation disclosed total occlusion of the above mentioned two arteries and postoperative aortography revealed that the entire splanchnic region was sup plied via a dilated collateral from the inferior mesenteric artery SUTTON too has described a case of superior mesenteric artery thrombosis that exhibited no serious clinical signs and in which aortography revealed a dilated collateral ex-tending from the left gastric artery PORSTMANN (1962) reported three cases with obliteration of the superior mesenteric artery with a wide collateral artery from the inferior mesenteric artery similar to that in the present cases without any clinical signs of impaired mesenteric circulation

These cases like our Case 3 demonstrate that occlusion of a splanchnic vessel may have an asymptomatic course In Case 4 collateral communications from the inferior mesenteric resembling those in Cases 2 and 3 were roentgeno logically manifest but in addition branches of the celiac artery extended from the dilated collateral The occlusion had apparently developed in a trunk common to the celiac and superior mesenteric arteries — a comparatively rare phenomenon — incidence 1 3 per cent in Europeans 2 4 per cent in Japanese (ADACHI 1928) Cases 3 and 4 moreover both exhibited fairly large tortuous vessels at the site of the suprarenal arteries (Fig 4) We have found no roent

genologic reports of such vessels, but GOLDZIEHER et coll (1951) have observed dilated tortuous vessels at the site of the adrenal glands at exploratory operation for clinically suspected pheochromocytoma Since the patient was found to have coarctation of the abdominal aorta, these vessels were regarded as collaterals Although the angiographic findings might represent dilated arteries in this region, we can offer no plausible explanation for the development of a collateral circulation from the suprarenal arteries to the splanchnic region No such angiographic findings have been reported in cases of suprarenal tumours (AHLBACK 1958, DENSTAD 1951, SUSSE & RADKE 1957)

The roentgenologic appearances in Case 5 could be attributable to thrombosis of the celiac artery with development of a collateral circulation from the superior mesenteric artery The upper abdominal organs were thus supplied via a single vessel arising from the aorta at the site of the superior mesenteric artery This case does not represent the anomaly that has been described under the designation truncus coeliaco mesentericus (ADACHI 1928, BUHLER 1904, MUNGER 1941) THANE in 1888 described an anatomical specimen in which a fibrous cord was present at the site of the celiac artery, and long, tortuous collaterals extended from the superior mesenteric artery HECHT (1905) observed similar collaterals in a case with gross stricture of the proximal celiac artery No lesions of the vascular wall were discernible in the stenosed area The vascular distribution in these last two cases appears to have been identical with the angiographic findings in our Case 5

The last two cases now reported were not operatively verified Since the absence of clinical signs of thrombosis could be indicative of a congenital anomaly, it seems justifiable to outline the development of the splanchnic vessels

Embryology The primitive aorta is paired but the two structures unite to form a dorsal aorta before the embryo is 3 mm long and dorsal, lateral and ventral branches are given off from this unpaired aorta in each segment The dorsal branches supply integument, muscle, and nerve tissue and are united via several longitudinal anastomoses The lateral branches develop into the phrenic, suprarenal and renal arteries, and the spermatic or ovarian arteries The ventral branches unite to form an unpaired intersegmental artery immediately after fusion of the aorta The union takes place according to BROMAN, by fusion of the two paired branches The intersegmental arteries pass to the embryonic gastrointestinal tract where they unite in a dorsal and a ventral longitudinal anastomosis The majority of these arteries undergo regression at an early stage, the time apparently being variable (TANDLER 1904, BROMAN 1908, PERNKOPF 1922) When the embryo has attained a length of 8 mm, ventral arteries persist only in four areas A vessel that becomes the celiac artery lies at the level of the fifth cervical segment A relatively large vessel, the omphalomesenteric artery, which later develops into the superior mesenteric

artery, takes its origin between the first and third thoracic segments The vessel that is later to become the inferior mesenteric artery runs from the twelfth thoracic segment Two relatively large vessels the umbilical arteries, which do not undergo fusion but remain paired, lie at the level of the third to fifth lumbar segments All splanchnic vessels are thus laid down well craniad then migrate caudad but not until the embryo has reached a length of 15 mm do their locations coincide with those in the adult (ANSON 1936—1937, HEIDSIECK 1928—1929 TANIGUCHI 1931) The ventral intersegmental arteries possess several roots at a very early stage and their caudal migration proceeds via the development of a caudal root and regression of the cranial root The possibility exists that during this caudal migration of the vessels anomalous sites of origin may appear TANDLER (1904) has shown that a trunk common to the celiac and superior mesenteric arteries could develop via a longitudinal anastomosis between the primitive roots coincident with regression of the origin of the celiac artery in the aorta This common trunk would have a retroperitoneal location behind the pylorus and pancreas and would not correspond to those anastomoses that normally exist between the celiac and superior mesenteric arteries BUHLER (1904) considered that these anastomoses are developed from the longitudinal ones ventral and dorsal to the primitive gastrointestinal tract

The mechanism of development in Case 4 may therefore have consisted in regression of the normal origins of both the celiac and the superior mesenteric arteries and development of the dorsal longitudinal anastomosis at the gastro intestinal canal into a long and tortuous collateral The origin of the celiac artery failed to develop in Case 5 and collaterals evolved at dorsal and ventral longitudinal anastomoses at the level of the primitive stomach

Although it is theoretically possible that the vascular abnormalities observed by the present writers were congenital anomalies there is no evidence to that effect No single instance of such anomalies can be found in the literature apart from the cases described by THANE and by HECHT The abnormal vascular distributions in the splanchnic region that have been described as developmental anomalies (ADACHI and MICHELS) conform to the above mentioned retro peritoneal pattern and do not as a rule involve the arcade arteries that normally occur in the proximity of the intestinal tract

Conclusions

The five cases described illustrate various possibilities in the development of collateral circulation between splanchnic vessels The collateral circulation which in four of the present five cases consisted of a substantial communication between the superior and inferior mesenteric arteries via the middle and left colic arteries was observed in one case of coarctation of the abdominal aorta and in two cases of acquired mesenteric occlusion While one of the last mentioned two cases had suffered an acute attack of severe abdominal pain the

other had no history of acute abdominal distress, the same being true of the remaining two, unverified cases with similar vascular abnormalities The angiographically observed vascular abnormalities could, theoretically, have been congenital but they bore no resemblance to the vascular anomalies most frequently encountered Since they were detected in three of 299 angiographies of cases of hypertension without acute abdominal symptoms, they were possibly attributable to slowly increasing local obstructions of the large splanchnic vessels near the aorta The similarity with central stenosis of, e g the renal arteries or the large cervical vessels, is striking, and the abnormalities might even in the two unverified cases be manifestations of the generalized vascular condition which leads to hypertension and which, by its localization, gives rise to stenosing processes in arteries supplying one or the other splanchnic area

SUMMARY

The history clinical picture and angiographic findings in five cases of abnormal collateral communications between the splanchnic vessels are compared and discussed

ZUSAMMENFASSUNG

Die Vorgeschichte klinischen Erscheinungen und angiographischen Befunde von ab normalen Kollateralen zwischen den Splanchlicus Gefässen werden beschrieben und analysiert

RÉSUMÉ

Les auteurs comparent et étudient l anamnese les signes cliniques et angiographiques de cinq cas de communications collatérales anormales entre les vaisseaux splanchiques

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ANGIOGRAPHICALLY DEMONSTRATED ARTERIOVENOUS SHUNTING IN CIRCULATORY OBSTRUCTIONS IN THE LOWER EXTREMITIES

by

ROLF KOHLER and VEIKKO VILJANEN

Exceptionally rapid and often profuse filling of the femoral veins was frequently observed in angiographies performed for vascular insufficiency in the lower extremities and was considered to be due to precapillary arteriovenous shunting. Since references in the roentgenologic literature to arteriovenous anastomoses are scanty and apparently inadequate, a systematic study of this phenomenon was performed in a large material.

Earlier investigations. Arteries, veins and capillaries are believed to originate from a common bed in the mesenchyma of the embryo (JORDAN 1930). Some vessels will grow into arteries and veins as their walls develop, others will persist as capillaries between the arteries and veins, and the remainder will form shunts between the latter. SEEGER (1938) in a comprehensive review of the development of the vascular system and its relationship to arteriovenous communications pointed out that the existence of the latter is generally accepted although clearly defined limits between the probably normal and the pathologic ones are not at once apparent.

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Fig. 1. Arteriovenous shunting in the regions of the vena circumflexa femoris lateralis and vena profunda femoris and filling of the proximal femoral vein. Distinct venous filling within 6 sec of start of injection. a) At 3 sec. b) at 12 sec.

Fig. 2. Shunting in the regions of the vena profunda femoris and vena circumflexa femoris medialis. Veins filled within 6 sec after start of injection. a) At 3 sec. b) at 9 sec.

Two types of arteriovenous shunts are usually distinguished:

1. Arteriovenous anastomoses in the limited sense and which meets the definition by CLARA (1956): regularly present direct connections between the arterial high pressure and the venous low pressure system which, by regulating their lumens, enable temporary shunting past the peripherally connected capillary system. Perhaps the earliest extensive study of arteriovenous anastomoses in man was that by SUCQUET (1862) in which these communications in various situations were described. Another early paper was published by HOYER (1877). CLARK & CLARK (1934) studied arteriovenous anastomoses in the ear of a living rabbit over a considerable period; their number varied between 25 and 55 per 1.6 cm² and their inside diameter between 5.6 and 63 μ. These authors were able to verify the two varieties observed by HOYER, i.e. the straight and the more numerous coiled anastomoses; the majority of the anastomoses arose from small arteries although occasionally from primary branches of the ventral artery of the ear.

2. Grossly abnormal arteriovenous communications in widely diversified areas of the body. These are often multiple and of small caliber, and may persist unobserved in a latent stage for many years, or for life. In other cases the shunts, originally very small, slowly develop into arteriovenous fistulae and produce signs. The transition from the diffuse changes, suggestive of hemangioma and



Fig 3 Shunting in the regions of the vena circumflexa femoris lateralis r mus asc and proximal femoral vein The veins were clearly visible at 6 sec a) At 3 sec b) at 9 sec

often called circoid aneurysms to more localized arteriovenous fistulas is gradual, and no definite pathologic difference is evident (ADAMS 1951, PIULACHS & VIDAL BARRAQUER 1953)

Arteriovenous fistulae of varying degree may occur in the lower extremities Marked phlebectasias perhaps increased length of the leg and cardiac changes may be present in the more marked cases and extirpation may be impossible in other cases the changes are usually local and respond well to surgery (LEWIS 1930 HORTON 1931) PIULACHS & VIDAL BARRAQUER claimed from conclusive evidence that idiopathic and postphlebitic varicosities are due to the same primary process the result of a congenital arteriovenous communication VOGLER (1953) stated that the anastomoses may be even larger than those indicated by CLARA but still meet the definition he gave these will probably be visible in ordinary roentgenograms

Technique of examination Arteriovenous shunting may be studied by serial angiography According to PIULACHS & VIDAL BARRAQUER contrast medium injected into the proximal femoral artery takes under normal conditions 3 to 7 seconds to reach the foot this arterial stage lasts for 10 to 15 seconds depending on the amount of contrast medium injected The succeeding capillary phase produces a uniform increase in opacity of the soft parts and lasts for 10 to 20 seconds although its start and end are hard to determine exactly The venous stage is characterized by its diffuseness caused by the relatively long time taken for the veins to become outlined The contrast medium that has reached the capillary system in the normal way may therefore according to the above data, be demonstrated in the veins at 20 seconds at the earliest PIULACHS & VIDAL BARRAQUER decided that the demonstration of the veins prior to 8 seconds following the injection of contrast medium will definitely mean an abnormally swift passage whereas their demonstration from the thirteenth second onwards must be interpreted as a normal transit time In the present work filling of the veins within 9 seconds was considered to suggest arteriovenous shunting



Fig 4 Filling beginning 6 sec after the injection in wide veins of varicose type in the regions of the profunda and pudenda externa a) At 3 sec b) at 12 sec

The angiographies of the lower limbs in the present investigation were always preceded by a series of films of the lower part of the aorta and the pelvic vessels The subject was then moved to another examination table fitted with a film changer Each limb was examined separately with a series of four 20 × 90 cm films usually exposed 3, 6, 9 and 12 seconds after the contrast medium injection was started, 20 to 25 ml Urografin 60 % were injected into the blood stream either through a polythene catheter introduced into the femoral artery by the Seldinger method or into the femoral artery through a proximally directed needle

Material and Results

The series is from the period from 1 January 1960 to 31 May 1962, and comprises 138 consecutive cases with signs of occlusive vascular disease within the distal part of the aorta or the vessels of the limbs The latter were examined *bilaterally as described above A case of congenital arteriovenous fistulae in the* upper part of a thigh and a case of shunts in a crural ulcer are also included in the present paper

The clinical diagnosis in 116 cases was arteriosclerosis obliterans, in 5 arterio*sclerosis diabetica, in 4 thromboangiitis obliterans in 5 embolus* and in 8 cases Raynaud disease Only 9 of the subjects were women Contrast medium was noted in the femoral veins 3 to 9 seconds after starting the injection in 49 cases, i e 35 %, in 31 cases this was observed on both sides

The incidence was roughly the same on the right and left sides and a catheter or needle injection had no influence on the incidence An increase in the peripheral resistance seemed to be the causative factor of shunting The latter occurred either through occlusion of the main trunk combined with a poorly de



Fig. 5. Wide veins of varicose type between Hunter's canal and the upper patellar margin evident at 9 sec. No shunting at higher levels of thigh. a) At 6 sec. b) at 12 sec.

Fig. 6. Shunting to popliteal and femoral veins at 9 sec. a) At 6 sec. Heavily ramified arteria genus inferior medialis, regular alternate changes in width in popliteal artery and main trunks of leg. b) At 12 sec. Almost all medium has passed into venous system. c) Angiography one year later. At 3 sec. the majority of the medium has passed into the proximal femoral and pelvic veins.

veloped collateral circulation or because the arteries of the leg were narrow and poorly filled. The rate of flow in the leg was retarded in these cases.

By far the commonest type of shunting present in almost half the number of limbs was evident in the regions of the vena circumflexa femoris lateralis and vena profunda femoris (Fig. 1). Predominant among the other types was rapid filling of the vena profunda femoris and vena circumflexa femoris medialis (Fig. 2). Other variants were a prominent vena circumflexa femoris lateralis ramus asc. and vena femoralis and the presence of some profunda trunks (Fig. 3).

Two thighs with femoral artery occlusion exhibited shunting into very wide veins within the profunda and pudenda externa region (Fig. 4). Arteriovenous communication may also occur in wide varicose veins in the distal thigh alone (Fig. 5). In one case a heavy arteriovenous transmission of contrast medium was noted in the patellar region where the vena saphena magna filled; minor venous pools were also noted lateral to the greater trochanter within 3 seconds of starting the injection of contrast medium.

Good filling of the popliteal and the femoral veins was noted in 3 cases and in these the shunt lay within the area of the densely ramified and somewhat tortuous arteria genus inferior medialis; corresponding widened veins channelled the flow of contrast medium to the large main trunk (Fig. 6 a and b). Profuse shunting via the proximal femoral veins to the pelvic veins was the unexpected finding on control angiography one year later (Fig. 6c).

Typical arteriovenous shunting in varicosities and a large ulcer of the leg is

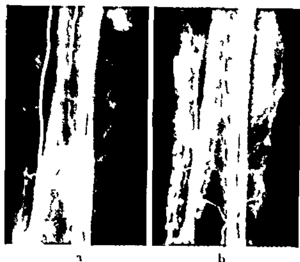


Fig 7 Arteriovenous communications in leg of man aged 52 with lifelong varicosities Rapid passage of medium in the arteries of the leg (20 cm/sec) a) At 6 sec Widened arteries directed towards the skin which at 9 sec (b) communi cate with a rich venous network

shown in Fig 7 The patient, a man of 52, had had unilateral varicose veins from childhood, the other leg was normal Cases of this type have been published e g by VOGLER (1953) and PIULACHS & VIDAL BARRAQUER

Arteriovenous communications, usually called arteriovenous fistulae, are de picted in Fig 8 A woman of 24 had had a swollen and aching limb with varicose veins since childhood, the left leg was 3 5 cm longer than the right, a common finding in these conditions (HORTON)

Discussion

Arteriovenous shunting of contrast medium in the thigh is common in angio graphies performed for obstructed circulation in the lower limbs SUNDER PLASSMANN (1943) assumed the existence of a special factor that in endangiitis obliterans resulted finally in the opening of the arteriovenous anastomoses while this was never observed in Raynaud's disease This author detected in roent genograms small bag like connections between arteries and veins, which seemed to correspond to the arteriovenous anastomoses Similar changes, a fraction of a millimeter in size, were observed by the present authors in some of the angio grams (i e Figs 1 and 7) These were large enough to represent contrast filled anastomoses, and if so, were groups of arteriovenous connections similar to those observed by CLARK & CLARK in the ear of the rabbit (Fig 9)

Unlike SUNDER PLASSMANN, WEIS (1951) noticed arteriovenous anastomoses in other vascular diseases as well as in endangiitis The opening of the shunts appeared to be proportional to the resistance of the precapillary system the resistance may have consisted of wall changes, obliterations of spasms in the vessels, or some other factor WEIS's article contains an illustration of arterio venous anastomoses in a hand with acrodermatitis atrophicans No exact in



Fig 8 Arteriovenous fistulae in proximal lateral part of thigh and communications of varicose type in upper leg in woman of 24 Rapid passage of contrast medium in the leg (15 cm/sec) a) b) c) At 3 6 and 12 sec respectively after injection

formation is provided on the exact situation of the arteriovenous communication observed in the lower extremities nor is there any evidence to support the roentgenologic findings

Early filling of the distal veins of the thigh via arteriovenous anastomoses in a case described as normal is illustrated in one of VOGLER s papers (1953) The publication apart from this mainly contains illustrations of anastomoses in the leg especially in crural ulcers

VOGLER in another paper (1954) draws attention to the significance of arteriovenous anastomoses when changes in circulation in the terminal arterial vessels of the leg occur PIULACHS & VIDAL BARRAQUER were interested only in arteriovenous communications in varicoses of the leg and the illustrations in the paper by MURPHY & MARGULIS (1956) were also mainly of legs they also included an example of considerable arteriovenous shunting in a hand after severe frostbite a condition that seems to predispose to shunting

The experience of the writers suggests that the peripheral resistance is the most important although not the sole factor determining the opening of arteriovenous anastomoses Pressure measurements were not performed It appears possible however roughly to assess peripheral resistance by (1) in open main trunks estimating the progress of the contrast medium at mid calf per time unit (2) in occlusions determining the efficacy of the distal circulation from the number and width of collateral vessels

The writers were by these criteria able to establish that arteriovenous shunting in the thigh occurs when the progress of contrast medium in the leg is equal to

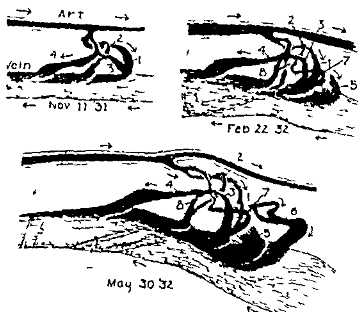


Fig 9 Three successive camera lucida drawings of the same groups of arteriovenous anastomoses from a stable reformed tissue chamber installed in a rabbit's ear (after CLARK & CLARK)

or less than 5 cm/sec and when the collaterals are poorly developed The value 5 cm/sec was reached empirically, LINDBOM (1951) gave it as the normal lower limit of arterial rate of flow No shunting occurs with a rate of flow in the 6 to 12 cm/sec range nor if the collaterals are well developed Shunting is again encountered, but is of another type if the rate of flow is still higher (cf Figs 7 and 8) Figs 6 and 14 provide examples of arteriovenous shunting when the flow of contrast medium is slow in the leg, while the main arteries in the thigh are open Fig 10 illustrates deficient conditions of flow in the right extremity and open arteriovenous anastomoses in the thigh while these are closed in the left extremity where the circulation is satisfactory

The flow of contrast medium is usually retarded in the upper part of the leg when the distal vessels are narrow and poorly filled, or are not outlined at all In one case, however, the retardation occurred first in the proximal part of the foot with resultant shunting in the proximal part of the thigh (Fig 11)

The resistance within the peripheral vessels, as already pointed out, is probably not the sole factor in determining whether arteriovenous shunting will develop The anatomoses are not merely passively functioning mechanical valves CLARK & CLARK in their in vivo experiments observed a lively dynamic action within the anastomoses, both of the continuous rhythmic type and in response to various stimuli The anastomoses may evidently remain closed under their own regulatory capacity even though a retarded rate of flow suggests increased peripheral resistance The present series included some cases of this kind

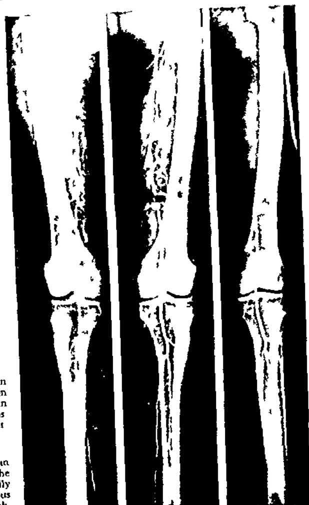


Fig 10a Fig 10b Fig 11

Fig 10 a) At 9 sec Poor circulation conditions in the right limb with open arteriovenous anastomoses especially in the region of the circumflexa femoris b) At 9 sec No obstruction nor shunting in the left limb

Fig 11 At 12 sec No obstruction in the thigh normal rate of flow in the leg (8 cm sec) retardation proximally in the foot and open arteriovenous anastomoses in proximal part of thigh

The arteriovenous anastomoses that open at angiographies performed for blocked circulation of the lower extremities have a highly diversified localization and degree of development as indicated by the examples previously quoted The findings are not even constant in the same case two consecutive contrast medium injections may yield considerably different results and a third angiography somewhat later may lead to another quite conflicting finding (Fig 12) The differences recorded after the first and second injections may be attributable to the dilatory effect of the contrast medium on the vessel which improves the peripheral blood flow and in this way reduces shunting (LINDGREN & TORNELL 1958) The extirpation of the aneurysm may well produce changes in the condi



Fig 12 Aneurysm produced by shell splinters in the proximal part of the femoral artery Constant claudication despite patent main arteries a) and b) First examination at 6 and 9 sec respectively Slow flow of medium (3 cm/sec) the bulk of which shunts over into the venous system c) and d) Repeat examination at 6 and 9 sec respectively Improved flow in the leg few open anastomoses e) and f) Aneurysm extirpated films at 6 and 14 sec Further improved proximal flow with retardation in distal part of leg shunting to the proximal femoral veins as well as via the patellar veins to the vena saphena magna

tions of flow and thus in the findings at a third angiography The totally different types of shunting in one limb in Fig 6 should be mentioned in this connection *There was no shunting, but persistent filling of the arteries, during the* whole period of the examination, and a slow rate of flow in the other limb, whereas the presenting clinical signs were symmetric Claudication occurred after walking 200 to 400 m, a condition that had persisted unchanged for 4 to 5 years

The sensitive reactions of the vascular system are also reflected by the examination findings in Fig 13 At the first angiography, practically all the contrast medium was shunted into veins that discharged mainly into the popliteal and the femoral veins At the next examination, 4 days later, the contrast medium appeared only in the proximal veins, and none was visible in the popliteal and femoral veins VOGLER studied in detail the effect of the intra arterial administration of Hydergin (Sandoz), the vasodilatory preparation, on arteriovenous



Fig 13 Slow flow in the leg (3 cm/sec) a) At 3 sec b) at 9 sec The bulk of the medium has passed into a widened femoral vein and branches of the circumflexa femoris Examination 4 days later c) At 9 sec mainly the proximal veins filled d) At 9 sec after injection and 10 min after intra arterial administration of 0 6 mg Hydergin Negligible shunting the contrast medium lies in the arterial system

anastomoses in crural ulceration and found that in most cases they closed The writers checked this functional capacity in the anastomoses to use VOGLER's expression in a few cases and arrived at similar conclusions Thus only traces of contrast medium were visible in the proximal part of the femoral artery in Fig 13d an angiography after 0 6 mg Hydergin intra arterially Similar angiographic findings before and after sympathectomy are also included in the present material (Fig 14)

Conclusions

There is conclusive histologic evidence of the occurrence of arteriovenous communications in mammals Living tissue studies especially of the rabbit's



Fig. 14. Slow contrast flow in the leg (5 cm/sec). a) At 6 sec. b) at 12 sec. Abundant *shunting in the thigh. c) and d) Angiography after sympathectomy. c) At 6 sec. The* medium has reached considerably farther distally than in (a). d) At 12 sec. A prominent *art. tibialis post. filled as far as the foot, negligible shunting in thigh.*

ear, have disclosed many topographic and functional details of this arterio-venous shunting (CLARK & CLARK). As regards the physiologic importance of the communication, however, one must agree with ILLIG (1961) that these experiments, just as *other research, have not yet been able decisively to solve the* problem of the capillary circulation or the general circulation. CLARA considered the arteriovenous anastomoses a regional special arrangement in the vascular system, but not a cornerstone in the terminal capillary bed of general physiologic or pathologic importance. VOGLER is however of the opinion that the arteriovenous anastomoses play an important role in circulation disturbances in the terminal arterial vessels.

The present results seem to indicate that arteriovenous anastomoses in the thigh deserve more attention than they have been accorded hitherto The angiographic method of demonstrating arteriovenous communications is a rough one if detailed information is desired but has valuable positive qualities Angiographies are easy to perform and seem to be able readily to record changes in blood flow conditions e g with double injections before and after sympathectomy or intra arterial spasm relaxing medication

The question however immediately arises as to whether the roentgen findings described above correspond to conditions in the vascular system as they are without vascular puncture and contrast medium injection or whether they are simply an artefact produced by these measures The shunting could e g be a result of vascular spasm (LINDBOM 1957) The cases that present evidence of shunting however, had either circulatory conditions permanently impaired by arteriosclerosis or were of the Raynaud type or in other words with a clinical picture suggesting a spastic etiology The present writers are inclined to agree with WEIS that in blocked circulation of the lower extremities the arteriovenous anastomoses in the thigh are there to regulate the flow of blood and the roentgen findings therefore reflect the physiologic course of events The anastomoses belong to the normal equipment of the vascular system and like sluices, if the conditions of flow become pathologic come into action in order to avoid stasis proximally to the block The arteriovenous anastomoses are not responsible for the reduced peripheral blood flow which is produced by the primary pathologic changes of whatever type they may be It would appear to the writers however that arteriovenous anastomoses in the leg in varicosities and crural ulcers, on the other hand represent a type intermediate between the normal anastomoses of the thigh and the wide definitely pathologic arteriovenous fistulae

SUMMARY

Filling of veins in different parts of the thigh 3 to 9 *seconds after the* start of the injection was frequently observed at bilateral angiography *in* 138 *cases* with circulatory obstructions and appeared to be due *to shunting* via open arteriovenous anastomoses The various types of anastomoses are described and their mechanism and function examined

ZUSAMMENFASSUNG

In 138 Fallen von Zirkulationsbehinderung *zeigten sich drei bis* neun Sekunden nach Injektion fur beiderseitige Angiographie gefullte Venen *in* verschiedenen Gegenden des Oberschenkels Dies erscheint verursacht durch *einen* Kurzschluss zwischen offenen arteriovenösen Anastomosen Die verschiedenen Typen dieser Anastomosen werden beschrieben *sowie* deren Funktion und Wirkungsart

RÉSUMÉ

Dans 138 cas d obstruction vasculaire des membres inférieurs les auteurs ont observé fréquemment par angiographie bilatérale une opacification de veines de diverses parties de la cuisse de 3 à 9 secondes après le début de l injection semblant due à un court circuit par des anastomoses artério veineuses ouvertes Ilsdécrivent les divers types d anastomoses et étudient leur mécanisme et leur fonction

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ACUTE CRANIAL TRAUMA

A preliminary report

by

G RUGGIERO R S LEIGHTON P DETTORI and F COLUMELLA

The technical aspects of the radiologic examination of cases of acute cranial trauma have been dealt with previously (LEIGHTON 1963 RUGGIERO 1962 RUGGIERO et coll 1963) It must be emphasized that such examinations are in general difficult and demand considerable experience on the part of those who undertake them

In the first six months following the opening of the department of neuro radiology in our hospital 46 cases of acute cranial injury were admitted Direct examination of the skull and carotid angiography were performed in all these cases as soon as possible after the injury bilateral angiography was carried out in 23 cases

Twenty even cases were verified at operation and constitute the material of this study The cases may be summarized as follows

Extracerebral hematoma (with or without brain laceration	14
Subdural hygroma	1
Intracerebral hematoma (with or without brain laceration)	4
Intra and extracerebral hematoma	1
Laceration without hematoma	7
Cerebral collapse	1
Depressed fracture without cerebral damage	1

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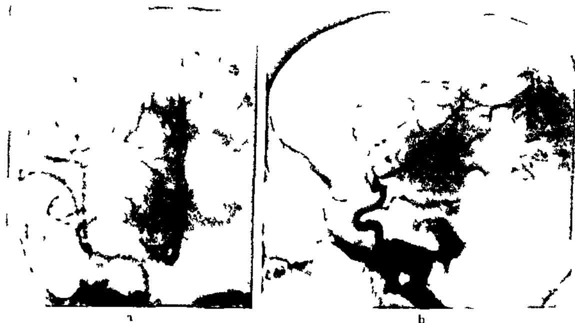


Fig 1 Typical appearances of recent (a few hours) subdural hematoma a) Slight displacement of pericallosal artery border of cerebral convexity smooth and regularly outlined b) Lateral practically normal appearances

An essential factor in the examination of cases of acute cranial trauma is the decision as to the side on which the examination is to be performed The clinical neurologic findings and the conventional roentgen examination of the skull will both play their part in determining the side Three possibilities have been considered

1 When the clinical neurologic findings were not in agreement with the indication of side, as shown by the displacement of the calcified pineal body, the examination was performed on the side indicated by the latter

2 In those cases in which neither the clinical neurologic findings nor a displaced pineal body indicated the side of the lesion, angiography was performed on the side indicated by fracture, if such was present

3 If the radiologic examination revealed a fracture, and the pineal body could not be made visible, whereas the clinical neurologic examination pointed to the side opposite to the fracture, the clinical indications were followed

Bilateral examinations were always performed in doubtful cases The criteria of the pineal displacement was correct in all cases in which the pineal body was seen to be displaced Surgery verified the findings in 15 of the 16 cases in which the clinical findings indicated the side Left hemiparesis associated with a left sided laceration was present in the 16th case Operation was however carried out on the correct side as a result of the angiographic diagnosis

Twenty one of the 27 at surgery verified cases had evidence of fracture in the conventional films Eight of these 21, however had unilateral fractures on



Fig 2 Left subdural hematoma 10 days after trauma Outline of hemisphere smooth and regular but concave marked displacement of the internal cerebral vein to the right The pericallosal artery was also markedly displaced the lateral view was negative

the side opposite to the surgical lesion in 5 of these 8 cases the clinical signs correctly indicated the side of the lesion A fracture is thus not a good guide for indicating the side of the lesion The correct side was examined first in all the 13 cases in which bilateral angiography was performed in 4 of these the fracture was on the same side as the lesion and in 3 the fracture was on the opposite side

A roentgenographic diagnosis of bilateral lesions was made in 3 cases, but confirmation of one of the sides is lacking because the surgeon in each instance decided that the clinical condition of the patient contraindicated exploration of the second side

These experiences have prompted a policy of action based upon indications as to the side of a surgical lesion in the following order of validity and significance (1) displacement of the pineal body (2) hemiparesis (3) anisocoria — mydriasis is usually on the side of the lesion and we feel that anisocoria may be a very important localizing sign as was also pointed out by COLLMELLA DEL ZANO & NICOLA (1959)

Right sided angiography in the frontal half axial projection has been performed in doubtful cases and thereafter the further examinations that may be indicated by the findings in these angiographic films Recently simultaneous biplane angiography of the right side has been carried out in such cases

Diagnosis

The pathologic features of cranial trauma may be divided into (1) contusions (2) extracerebral hematomas extradural or subdural (3) lacerations (4) intracerebral hematoma The last three are frequently found together

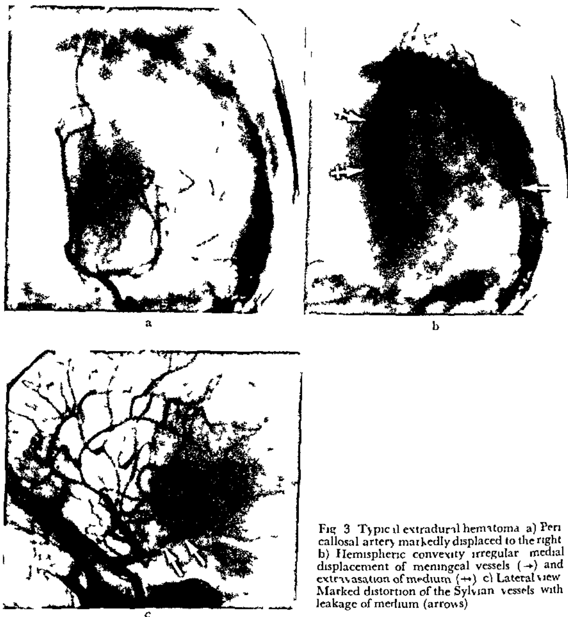


Fig 3 Typical extradural hematoma a) Pericallosal artery markedly displaced to the right b) Hemispheric convexity irregular medial displacement of meningeal vessels (→) and extravasation of medium (↠) c) Lateral view Marked distortion of the Sylvian vessels with leakage of medium (arrows)

Contusions In this group are included cases not surgically verified and those in which minimal changes were found at angiography, e g slight displacement of the anterior cerebral artery suggesting the advisability of expectant treatment Generally speaking these showed, in association with the clinical improvement, a return to normal roentgenographic appearances

Extracerebral hematomas The diagnosis is based upon the demonstration at angiography of a non vascularized space between the cerebral hemisphere and the cranial vault, the hemisphere being indicated by the extreme limits of the

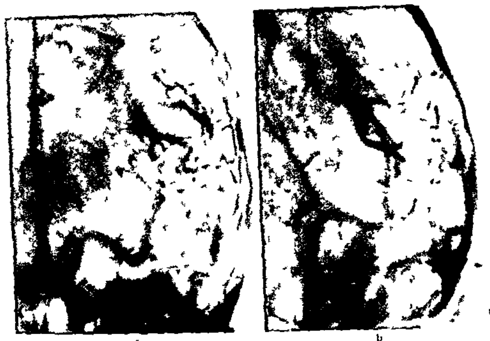


Fig 4 Localized left extradural hematoma Outline of cerebral convexity irregular avascular region well demonstrated in the tangential view only (b)

vessels of the convexity If the technique is correct it is difficult to miss the diagnosis The diagnosis of extracerebral hematoma was correctly made in all the 14 cases of extracerebral hematoma (either alone or in association with other lesions) The problem becomes much more difficult when an *attempt is made* to differentiate between extradural and subdural lesions excepting of course such involving the midline and *displacing the superior* sagittal sinus downward (WICKBOM 1948)

The presence of an extradural lesion is beyond doubt if a rupture of the meningeal vessels is demonstrable (LINDGREN 1954) The most characteristic appearance is a collection of contrast medium outside the vessel (Fig 3 c) An effusion of medium may however also be observed outside the brain (Fig 3b) This is likewise *true* of the displacement and deformation of these meningeal vessels as the present writers have demonstrated (RUGGIERO 1962, RUGGIERO et coll 1963) It is evident that good demonstration of the branches of the external carotid artery *must* be obtained and in many cases this is unlikely without direct puncture of this vessel in the neck It is however at times possible to show these vessels more or less isolated from those of the internal carotid artery by means of appropriate seriography when the common carotid artery *is injected* This results from the fact that the velocity of circulation in

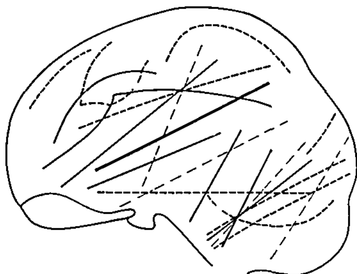


Fig 5 Relationship between position of fracture and the intracranial lesion The thin black lines (—) indicate fractures with extradural hematoma — — — — with laceration only the thick black line (—) indicates fracture with subdural hematoma and — — — with laceration and hematoma

the internal carotid is different from that in the external carotid artery The blood flow is usually slower in the latter although the reverse may occur (in deep coma, in which the brain circulation is retarded) The branches of the external carotid artery may thus appear in the films either before or after those of the internal carotid artery

Apart from the data on the modifications of the external carotid artery, a few attempts to distinguish an extradural from a subdural hematoma by internal carotid angiography have been reported in the literature The authors seem to agree that this is very difficult WICKBOM, and LINDGREN have pointed out that subdural lesions are more likely to be located above the Sylvian fissure The present authors have however observed a subdural hematoma also involving, and sometimes only involving, the inferior part of the convexity BORELLI, ROMANI & HUEBER (1957) stated that an extradural hematoma leads to less displacement of the pericallosal artery than a subdural hematoma, since in the former the attachments of the dura resist the expansion of the hematoma They also pointed out the importance of the characteristic semilunar aspect of a subdural hematoma BONNAL & LEGRE (1958) reported that, unlike a subdural hematoma, an extradural hematoma does not extend over a large part of the convexity of the brain, but tends to be more localized NORMAN (1956) stated that he knew of no definite way of differentiating between a subdural and extradural hematoma except by the observation of a downward displacement of the sagittal sinus He, however, went on to describe the following characteristic differential points between an extradural and subdural hematoma (1) an extradural hematoma tends to be more localized, (2) it usually has an irregular outline while the outline of a subdural hematoma generally forms a smooth curve, (3) an extradural hematoma often appears to bulge into

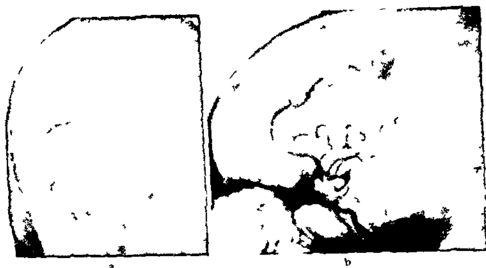


Fig 6 Small anterior basal right temporal laceration a) The anterior part of the pericallosal artery is slightly displaced towards left b) The carotid siphon and the anterior Sylvian fissure vessels are elevated and displaced medially

the brain substance while a subdural hematoma appears to displace the brain en masse

The writers feel that an extradural hematoma may be differentiated from a subdural hematoma by the appearances of the internal carotid vessels in relation to the shape of the avascular space (Figs 1 to 4) The material has been reexamined solely from this point of view An avascular space limited medially by the cerebral convexity and appearing as a smooth and regular curvilinear line has been considered as characteristic of a subdural hematoma This curvilinear line is convex in a very acute case and seems to tend to become concave with the passage of time In the case of an extradural hematoma on the other hand the cerebral cortex usually has an irregular border and a superimposition of vessels on the avascular area is frequently noted since the collection is in general less voluminous and more localized A subdural hematoma usually presents nearly normal appearances in the lateral view while an extradural hematoma almost always leads to localized deformation of vessels The diagnosis of extradural hematoma was made on the basis of these criteria on reexamination in 9 cases in 7 of these the operative findings were in agreement

The differential diagnosis between a subdural and extradural hematoma is of course helped by the clinical history in which the anamnesis is generally much shorter in extradural hematoma and there is no lucid period The presence of fracture is much more frequent with the extradural lesion Of the 14 hematomas in the group 6 of which were of the subdural type alone 3 were associated with cranial fractures while of the 7 extradural hematomas 6 were



Fig 7 Left intracerebral and small subdural hematoma and frontal temporal basal laceration a) The avascular area indicates a subdural hematoma but it is too small to account for the degree of displacement of the pericallosal artery b) The backward displacement of the pericallosal artery and the downward displacement and stretching of the Sylvian arteries indicate laceration of the brain

associated with such fractures Fig 5 is a composite drawing in which the relationship between the site of the main fracture and the associated cerebral lesion is analysed This drawing shows that a laceration is usually associated with a fracture situated high on the convexity or near the base of the skull These data have naturally to be treated with caution and need further confirmation in many more cases

Lacerations Laceration is a traumatic interruption of the continuity of the brain convexity with the formation of necrotic tissue, which gives rise to anoxemia and edema The importance of this kind of lesion has been emphasized by one of the authors of this paper (F C) (COLUMELLA et coll 1959) who insisted on the advisability of surgical treatment As a matter of fact, in too many centres the absence of a hematoma is considered an indication for non surgical treatment, and it would appear that some patients are lost who could have been saved by early operation There are 11 cases of verified laceration of the brain in the present material The site most frequently involved is the convexity of the temporal lobe (9 cases), in 2 of these there was also laceration of the parietal lobe and in 3 of the frontal lobe, in the 2 cases not involving the temporal lobe, the lesion was in the frontal lobe

The angiographic aspect of a laceration is the demonstration of the existence of a localized expansive process often basally situated Lacerations usually produce less displacement of the pericallosal artery than extracerebral hematomas The differential diagnosis between an intracerebral hematoma and laceration is difficult The degree of displacement of the pericallosal artery may even here be helpful i e the displacement is usually less in the laceration but the diagnosis will probably be indicated in the lateral view in which minor distortions of either the carotid syphon or the Sylvian group vessels will suggest the presence of a laceration (Figs 6 and 7) This is of course frequently encountered because the anterior portion of the temporal lobe is the most common site for lacerations ANDERSEN (1958) working with spontaneous cases of intracerebral hematoma has demonstrated that the lesion when deep may be diagnosed by the displacement of the lenticulo striate arteries

There is only one case in the present material of intracerebral hematoma alone but 3 cases of intracerebral hematoma associated with laceration Such a material as this is too small to justify definite conclusions but at the same time it is felt that the findings of a basal lesion especially if situated in the temporal region are more in favour of a laceration Moreover as WICKBOM also stated the presence of an intracerebral hematoma must be suspected in cases in which the displacement of the pericallosal artery is too great to be explained by the lesion that is demonstrated The present writers have recently observed a case not included in this material in which an extradural hematoma subdural hematoma and a laceration were present together and in which the diagnosis of all three lesions was made preoperatively from the angiographic findings

These lacerations are often accompanied by hematoma and in the present material the latter was present subdurally in 3 cases intracerebrally in 2 cases subdurally and extradurally in one case and subdurally and intracerebrally in one case As previously stated the relationship between fractures and lacerations may also be of some interest The study of this material has shown that a temporal laceration is often associated with a low lying fracture and that a frontal laceration tends to exist with a fracture high and anteriorly on the convexity Even in those cases in which the fracture is situated at some distance from the frontal temporal region the laceration is apt to be present at one of these sites The practical aspect is that when a fracture is present and the patient is in poor condition or the angiographic signs of local abnormality are minim l a temporal laceration is still highly probable

SUMMARY

A material of 27 verified cases of acute cranial trauma is discussed with special reference to the radiologic approach Particular attention is paid to the differential diagnosis between extradural and subdural hematomata as well as to the problem of laceration of the brain

ZUSAMMENFASSUNG

Ein Material von 27 bestätigten Fällen von akutem Gehirntrauma wird besprochen, besonders in Hinsicht auf das röntgenologische Vorgehen. Besondere Aufmerksamkeit wird der Differentialdiagnose von subduralem und extraduralem Hämatom gewidmet und der Frage der Gehirnzerreissung.

RÉSUMÉ

Les auteurs étudient, en particulier au point de vue de l'examen radiologique, une série de 27 cas vérifiés de traumatismes craniens au stade aigu. Ils s'attachent particulièrement au diagnostic différentiel entre hématomes extra et sous duraux et au problème de l'attrition cérébrale.

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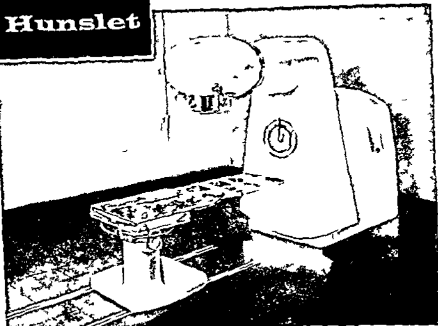
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THREE YEARS EXPERIENCE OF PERORAL CHOLEGRAPHY

by

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Over 3 000 examinations of the biliary tract with Biloptin have been described in more than 40 papers since this peroral cholegraphic contrast medium was introduced three years ago and one and a half million doses of Biloptin and Solu Biloptin have been sold throughout the world during this same period The present communication is an evaluation of this relatively new method of examination The merits of Biloptin and Solu Biloptin are considered and contrasted with reference to previous publications and to the writers own material of 249 patients

The study of the bile ducts and gallbladder as functional entities following the ingestion of contrast media was the aim of radiologists for many years The introduction of tri iodized contrast media e g Telepaque Teridax Orabilix improved the possibility of demonstration of the bile ducts The outlining of the ducts was however conditional upon a previous filling of the gallbladder for it was dependent upon a secondary filling of the ducts after the gallbladder had emptied There are relatively few references to primary filling of the bile ducts by the peroral method Twiss et coll (1955) by means of double doses

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of Telepaque combined with camphor tincture succeeded in demonstrating the bile ducts in 74 (72 %) of 106 patients who had undergone cystectomy. There is, however, no mention of the quality of the filling, the side effects, or contrast residues in the bowels. STAMATIKOS & TABER (1957) were successful in filling the bile ducts in 48 (71.4 %) out of 67 patients in whom there was no gallbladder filling; they gave a second dose of Telepaque 12 hrs later. TEPLICK et coll. (1958) reported that in 112 investigations with a single dose of Orabilix, the bile ducts were filled in 2 out of 5 patients in whom the gallbladder was not seen. TWISS & GILLETTE (1959) modified their previous method of fractionated administration of three doses of Telepaque by combining them with tinct. camph. and succeeded in 46 patients, in whom routine cholecystography had previously failed, in filling the gallbladder in 33 and the bile ducts in 29 patients. LORINC (1959) published the results of an analysis of 6 710 cholecystographies with Telepaque. This author was able to demonstrate the bile ducts in 334 patients, in whom the gallbladder had not filled, by the administration of a second dose 24 hours later. Moreover, the site of the occlusion of the cystic duct was located in 79 patients.

It is perhaps surprising that peroral cholegraphy was not generally used sooner. One of the reasons may have been the relatively poor filling of the bile ducts. Intravenous cholegraphy with Biligrafin, introduced in 1952, soon became the method of choice for studies of the ducts. The authors who compared Telepaque and Biligrafin appeared to prefer the latter. SUTTON & TILLET (1954) wrote: 'In our experience Telepaque shows only the common and cystic ducts, and the hepatic ducts, so regularly seen with Biligrafin, are not demonstrated'. SHEHADI (1957) thought that the hepatic ducts in functional and surgical cholecystectomy 'could not be adequately and consistently shown with Telepaque'. FISHEDICK (1955) demonstrated the bile ducts with Telepaque in only 5 patients but with Biligrafin in 51, in a series of 61 patients. BUCHTALA & WALTER (1958) in comparing the results of investigations with Biliselectan, Telepaque, Teridax, Baygnostil and Biligrafin in groups of 100 patients came to the conclusion that Biligrafin was the preparation of choice for the demonstration of the bile ducts.

After reports on side effects and complications (HORNYKIEWYTSCH & STENDER, THEANDER, SALTZMAN) and, occasionally, fatal sequelae (FROMMHOLD & BRABAND) from the use of Biligrafin, more attention was paid to peroral cholegraphy.

New contrast media for peroral cholegraphy were put on the market in 1959: Biliodon Natrium (AB Leo, Halsingborg, Sweden) and Biloptin and Solu Biloptin (Schering AG, Berlin, Germany). In the same year the first reports on Biliodon Natrium appeared from GUNNARSON, SALTZMAN and VIRTAMA, and on Biloptin and Solu Biloptin from HARWART et coll., BOGATZKI, CRECELIUS, KEINER, MULLER & SIELAFF.

Different methods of administering Biloptin and Solu Biloptin have been

described Many authors (BRANNAN et coll BUCHTALA, CRECELIUS FELSER, GOEMAERE KEINER KEMP & WRIGHT MANTON SIMON et coll WHITE & FISCHER) mostly employed a single dose A fractionated administration of Biloptin and Solu Biloptin was used by BOGATZKI GOERKE KEMP & WRIGHT MURRAY SCHACHERL WALTHER and WHITESIDE Most of these authors give the first dose in the evening and the second in the morning while some give Biloptin as the evening dose and Solu Biloptin or Biligrafin as the morning dose

A double dose of Biloptin or Solu Biloptin was given by BORIS & SILLE GOEMAERE GVOZDANOVIC & KALLAI KOHLER & HOLSTI LUDIN & LAUCHENALER MULLER & SIELAFF PELOSCHEK ROBINSON, SALTZMAN and exceptionally by WALTHER and WHITESIDE the medium was given on an empty stomach KONNER, as well as RICHTER et coll administered a double dose after a meal BAUMANN et coll gave Solu Biloptin intraduodenally and NAUMOFF rectally ZUBIAURE and CAPANDEGUY combined a single dose of Biloptin with the injection of morphine and vitamin C

The method of administration thus varies considerably and in view of the differences in the structure of the material as well it is obvious that a comparison of results is somewhat difficult

Terminology Simultaneous investigation of the bile ducts and gallbladder is still described by different terms Cholecysto-cholangiography (BOGATZKI BUCHTALA ROKA WALTHER), cholangio-cholecystography (LUDIN & LAUCHENALER) and cholecystangiography (GOERKE KARPATI, MURRAY) The last appears unsuitable as suggesting angiography of the gallbladder The present writers believe the most convenient word to be cholegraphy (SHEHADI GUNNARSON SALTZMAN VIRTAMA, GVOZDANOVIC & KALLAI) and comparable to the term urography The terms peroral cholegraphy and oral cholegraphy are both used to describe the investigation performed with the orally administered contrast media (SHEHADI STAMATAKOS & TABER TWISS et coll WHITESIDE)

Chemistry Biloptin is the sodium salt of β /3 dimethylamino-methylenamino-2 4 6-tri iodophenyl/ propionic acid while Solu Biloptin is the calcium salt of the same preparation The chemical structure and the experimental investigations of the pharmacologic properties of Biloptin and Solu Biloptin have been widely reported (SALTZMAN KIMBEL & LANGECKER KOHLER & HOLSTI) and particularly by BOGATZKI CRECELIUS HARWART et coll and LUDIN & LAUCHENALER

Trial of methods Our investigations were inaugurated late in 1959 The primary aim was to establish the simplest and safest method for the ambulatory roentgenologic examination of the hepatobiliary system as a functional entity In employing Biloptin it was hoped to avoid the unfavourable effects of Bili-

grafin, i.e. the danger of side effects and complications, but at the same time securing the advantages of primary filling of the bile ducts and gallbladder in addition to a short duration of the examination. It was decided to exclude the combined application of Biloptin in the evening and Biligrafin in the morning, intraduodenal or rectal administrations, and associated injections of morphine and vitamin C from the investigation.

Three methods therefore remained: (1) the administration of a double dose of Biloptin or Solu-Biloptin to the fasting subject, (2) the administration of a double dose of the media after a meal, and (3) the fractionated administration of the media in the evening and morning. The method of administering a double dose of the contrast medium on an empty stomach, called in this paper the 'standard method', seemed from the beginning the most convenient.

Comparative studies of the standard and fractionated methods were performed in 8 patients. The filling of the gallbladder by the fractionated method was established to be no better than by the standard method, while the demonstration of the bile ducts was less certain, side effects were not less common and the duration of the examination was extended to 15 to 18 hours. The standard method and the 'double dose after breakfast technique' were compared in 10 patients. The latter method yielded results equal to those with the standard method, but the examination lasted for 6 to 9 hours because of the slower emptying of the stomach, while the disturbances were not less than when the medium was given on an empty stomach; furthermore, the gallbladder appeared to be hypertonic and smaller than with the standard method.

Routine procedure adopted

The results of the comparative examinations prompted the adoption of the following routine procedure: the contrast medium was administered to the fasting subject at 6 a.m., in doses of 12 capsules of Biloptin or two doses of Solu-Biloptin suspended in 2 dl tapwater. Roentgenograms were obtained at 3, 4, and 5 and a half hours after the ingestion of two egg yolks; the films were obtained in both erect and prone postures. Tomography was widely employed. The examination was prolonged, if necessary, up to 24 hrs in selected cases.

Material. In total, 249 examinations with the double dose fasting technique were performed, 14 of these investigations consisted of controls in healthy subjects. Thirty-five of the patients had undergone cholecystectomy. Biloptin was used in 228 examinations and Solu-Biloptin in 21.

In addition, 8 investigations by the fractionated method, and 10 by the double dose post carnis technique were carried out in the same material.

One hundred and fifty-two of the patients were women and 97 were men, the average ages being 45 and 47, respectively. The youngest patient was 14 years old and the oldest was 81. Forty-six patients (30 females and 16 males) were over 60 and 9 of these were over 70 years.

Table 1

Analysis of gallbladder filling in 200 peroral cholegraphies showing incidence of stones

Patients	Very good	Good	Poor	Absent	Filled
	94	34	9	63	137
200	(21 s)	(16 s)	(8 s)		(45 s)
	47	17	4 5	31 5	68 5

s — Stones

Peroral cholecystography with tri or di iodized contrast media was performed in 112 patients before the examination with Biloptin or Solu Biloptin A control examination with Biligrafin was made in 64 patients after the one with Biloptin or Solu Biloptin

Results

The results of the demonstration of the gallbladder and bile ducts are signified as very good good poor, and 'absent Tomography was often necessary for the analysis of the filling labelled as 'poor and stones were found in the gallbladder in 8 and in the bile ducts in 2 of these examinations Stones are signified by s and dilated bile ducts by d in the tables

Both the gallbladder and bile ducts were outlined in all the 14 healthy subjects examined fasting with a double dose of Biloptin the demonstration of the gall bladder was very good in 11 good in one and poor in two patients, and of the bile ducts it was very good in 4 good in 6 and poor in 4 subjects The ages ranged from 18 to 22 years The side effects consisted of nausea in one vomiting in one and headache in one subject Residues of the medium were noted in the stomach in 3 examinations and in the small intestine in one examination

The gallbladder in 200 patients filled in 137 (68 5 %) and contained stones in 45 the gallbladder failed to fill in 63 patients (31 5 %), in 11 of whom stones were evident Stones were thus present in 56 of the 200 patients (Table 1)

The bile ducts filled in 180 instances (90 %) in the 200 patients with gall bladder they were dilated in 19 and contained stones in 6 patients Neither the gallbladder nor the bile ducts were demonstrated in 20 patients (10 %) An analysis of the results of the filling of the bile ducts is presented in Table 2

Table 2

Analysis of bile duct filling in 200 peroral cholegraphies showing incidence of stones and dilated ducts

Patients	Very good	Good	Poor	Absent	Filled
	32	99	49	20	180
200	(1 d)	(4 s 13 d)	(2 s 5 d)		(6 s 19 d)
	16	49 5	24 5	10	90

s Stones
d Dilated bile ducts

Table 3

Analysis of bile duct filling in 25 peroral cholegraphies in patients who had undergone cholecystectomy

Patients	Very good	Good	Poor	Absent	Filled
	3	18	8	6	29
35		(3 s 7 d)	(5 d)		(3 s 12 d)
	8 5 %	51 4 %	22 8 %	17 2 %	82 8 %

s = Stones
d = Dilated bile ducts

The bile ducts filled, but the gallbladder failed to do so, in 43 patients This could be assumed to be due to an obstruction of the cystic duct or to the gall bladder being packed with stones In these, the bile ducts were dilated in 12 and contained stones in 5, in 10 patients of this group the site of the obstruction in the cystic duct was located

The bile ducts were demonstrated in 29 (82 8 %) out of 35 patients who had undergone cholecystectomy They were dilated in 12 and contained stones in 3 (Table 3)

The bile ducts were demonstrated in 223 (89 6 %) of the total material of 249 subjects, including the controls They contained stones in 9 and were dilated in 31 Neither the gallbladder nor the bile ducts could be demonstrated in 26 cases (10 4 %) (Table 4)

Only in 137 of the total material of 249 subjects could the diagnosis be established by means of the contrast media previously used in cholecystography, filling was also obtained in all these with Biloptin and Solu Biloptin This number should be even smaller, as practice has shown that a certain percentage of the gallbladders that filled with Biloptin or Solu Biloptin failed to do so with other contrast media It was possible however to carry out analyses by the administration of Biloptin or Solu Biloptin in another 73 patients (43 with functional cholecystectomy and 29 with surgical cholecystectomy) in whom primary demonstration of the bile ducts was achieved, although the gall bladder did not fill

By giving a double dose of the cholegraphic media on an empty stomach, the diagnosis was possible in 223 out of a total of 249 subjects examined

Table 4

Analysis of bile duct filling in the total material including the controls of 249 peroral cholegraphies showing the incidence of stones and dilated ducts

Patients	Very good	Good	Poor	Absent	Filled
	41	121	61	26	223
249	(1 d)	(7 s 20 d)	(2 s 10 d)		(9 s 31 d)
	16 5 %	48 5 %	21 6 %	10 4 %	89 6

s = Stones
d = Dilated bile ducts



Fig 1 Comparative examinations with Biligrafin and Biloptin in one and the same patient a) 3 hours after the injection of 20 ml Biligrafin forte Only the upper two-thirds of the gallbladder are filled with the medium simulating normal findings good filling of the bile ducts b) Tomogram of (a) No gall stones visible

A control examination with Biligrafin was performed in 64 patients The findings were identical in 39 patients (61 %) The gallbladder that filled well with Biloptin failed to do so with Biligrafin in two instances and in three patients the demonstration of stones in the gallbladder was more successful with Biloptin than with Biligrafin (Figs 1 and 2) On the other hand the gallbladder in 10 patients filled well with Biligrafin while it failed to do so with Biloptin in 9 of these it contained stones The bile ducts that did not fill with Biloptin or Solu Biloptin were demonstrated with Biligrafin in 13 instances and contained stones in three Only in one patient was no demonstration of the gallbladder and bile ducts obtained with Biloptin while Biligrafin produced normal filling This was probably due to disturbances in the resorption

The results of examinations by means of Biloptin and Solu Biloptin in 84 patients in whom the gallbladder had completely failed to fill in earlier attempts with the routine technique for peroral cholecystography are shown in Table 5

It will be seen that in 49 patients (58 3 %) the gallbladder which had not been demonstrated with other contrast media was now filled It contained stones in 25 patients while it appeared to be without obvious changes in 24 The bile ducts in the same 84 patients filled with the cholegraphic media in 71 (84 5 %) were dilated in 11 and contained stones in one patient In 17 pa

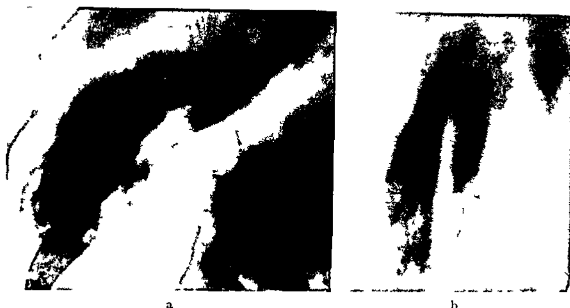


Fig 2 Same patient as in fig 1 but two weeks later and 5 hours after double dose of Biloptin on empty stomach A large number of gallstones are evident in the fundus and lower third of a trabeculated gallbladder poor filling of the bile ducts b) Tomogram of (a) Excellent definition of stone sizes (Verified at operation)

tients, an obstruction of the cystic duct could be assumed, and in 5 it was possible to localize it In only 13 patients (15 4 %) from this group had attempts to demonstrate the gallbladder and bile ducts by means of the peroral chole graphic media met with failure

Side effects Consideration was paid to side effects in 222 subjects Of these, 126 (56 75 %) had no symptoms, 65 (29 2 %) had nausea, 16 (7 2 %) had diarrhoea, 10 (4 5 %) had vomiting and 4 (1 8 %) headache One patient (0 4 %) showed a moderately strong allergic reaction The nausea was severe in only 3 instances

Table 5

Analysis of 84 peroral cholegraphies in patients in whom previous routine peroral cholegraphy had failed to produce filling of the gallbladder or bile ducts

Patients		Very good	Good	Poor	Absent	Filled
	Gallbladder	28	15	6	35	49
		(10 s)	(9 s)	(6 s)		(25 s)
84		33 3 %	17 8	7 1 %	41 7	58 3
	Bile ducts	9	49	13	13	71
		(1 d)	(7 d)	(1 s 3 d)		(1 s 11 d)
		10 6 %	58 3	15 5	15 5 %	84 5

s = Stones
d = Dilated bile ducts

Table 6

Analysis of gallbladder and bile duct filling in 178 peroral cholegraphies in patients who had not undergone previous operation with reference to side effects

Side effect	Patients	Very good	Good	Poor	Absent	Filled
A Gallbladder						
No reaction	100	45 (11 s) *45*	19 (10 s) *19*	5 (4 s) *5*	31 *31 %*	69 (25 s) *69*
Nausea	53	28 (6 s) *52*	6 (3 s) *13*	3 (3 s) *5 6*	16 *30 2 %*	37 (12 s) *69 8*
Diarrhoea	14	9 (2 s) *64*	3 (1 s) *21*	1 (1 s) *7*	1 *7*	13 (4 s) *98 2*
Vomiting	9	3 (1 s) *33 %*	2 *22*	0 *0*	4 *44 5*	5 (1 s) *55 5*
Headache	2	2 (1 s) *100*	0	0	0	2 (1 s) *100*
B Bile ducts						
No reaction	100	14 *14 %*	56 (1 s 7 d) *56*	20 (1 s 2 d) *20*	10 *10 %*	90 (2 s 9 d) *90*
Nausea	53	11 (1 d) *20 7 %*	22 (3 s 2 d) *41*	15 (2 d) *28 3*	5 *9 5 %*	48 (3 s 5 d) *90 5*
Diarrhoea	14	2 *14*	8 *57 6*	4 (1 d) *28 4*	0 *0*	14 (1 d) *100*
Vomiting	9	0 *0*	4 *44 4 %*	4 *44 4*	1 *11 1*	8 *88 8*
Headache	2	1 *50*	1 *50*	0 *0*	0 *0*	2 *100*

s Stones
d Dilated bile duct

Absorption The absorption of the media was checked in all 249 cases No residue of contrast medium was found in the right hypochondrium in 154 cases (61 8 %) Small quantities of medium were present in the stomach and duodenum at 3 to 5 hours in 74 patients (29 6 %) and in the small intestine at 5 to 8 hours in 21 (8 4 %) In no instance did the residues of medium appreciably interfere with the interpretation of the films The remains of the unabsorbed medium were easy to distinguish from the bile containing the excreted medium in the duodenum and small intestine

Influence of side effects on the results of peroral cholegraphy It was considered that an analysis of the results of the examinations with special reference to the ac

Table 7

Analysis of duct filling in 30 peroral cholegraphies in patients who had undergone previous cystectomy with reference to side effects

Side effect	Patients	Very good	Good	Poor	Absent	Filled
No reaction	15	1	9	3	2	13
			(1 s 5 d)	(2 d)		(1 s 7 d)
		6 6 %	*60 %*	*20 %*	*13 4 %*	*86 6 %*
Nausea	12	2	7	0	3	9
			(2 d)			(2 d)
		16 6 %	*58 3 %*	*0*	*25 %*	*75 %*
Diarrhoea	2	0	2	0	0	2
			(2 d)			(2 d)
			100 %			*100 %*
Headache	1	0	0	1	0	1
				100		*100 %*

s = Stones
d = Dilated bile ducts

companying side effects would be of practical value Nausea was by far the most frequent side effect in the material A proper evaluation of this disturbance is, of course, difficult and by some authors, e g , RENCK, was not attempted

Side effects were registered in 178 patients who had not undergone operation, and these are shown in Table 6

Minimal differences in the percentage of filling of the gallbladder and bile ducts were evident in patients with no disturbances, with nausea, headache and even with diarrhoea In 9 patients, who vomited part of the medium the gallbladder filled only in 5 (55 5 %), whereas in 8 (88 8 %) of these 9 patients the bile ducts were outlined with four good and four poor results

An analysis of the filling of the bile ducts in 30 patients who had undergone cholecystectomy with reference to side effects is shown in Table 7

The differences in the filling of the bile ducts were minimal excepting that nausea produced rather less frequent filling

Influence of medium resorption on the results of peroral cholegraphy The filling of the gallbladder and bile ducts naturally also depends on the time the resorption of contrast medium begins Optimal filling of the bile ducts was obtained at 3 hours and of the gallbladder at 5 hours in this material, provided the stomach emptied normally An analysis of the results with special regard to the emptying of the medium from the stomach and resorption in the intestine in all the examinations is shown in Table 8

It will be seen that the highest percentage of demonstration of the gall bladder was recorded in the group in which no residues were found and complete resorption could be supposed A poorer filling occurred when remnants of medium were evident in the small intestine, and poorer still when residues lay in the stomach

Table 8

Influence of resorption of the contrast medium on the results of peroral cholegraphy

200 Patients (no operation)

Patients	Remains of medium		Very good	Good	Poor	Absent	Filled
1 3	None	Gallbladder	64	20	6	33	90
			(15 s)	(11 s)	(5 s)		(31 s)
			5?	*1[illegible] ? %*	*4 8*	*7 %*	*[illegible]3*
		Bile ducts	23	59	30	11	112
				(2 s 9 d)	(1 s 4 d)		(3 s 13 d)
			18 6	47 9	*?4 3*	9	*91*
63	Stomach 3—5 hrs	Gallbladder	24	12	2	2[illegible]	38
			(4 s)	(4 s)	(2 s)		(10 s)
			38	*19*	*3 1*	*39 7*	*[illegible]0 3 %*
		Bile ducts	8	30	16	9	54
			(1 d)	(2 s 2 d)	(1 s)		(3 s 3 d)
			12 7	*47 6*	*25 3*	*14 3*	*85 7*
14	Small intestine [illegible]—8 hrs	Gallbladder	7	1	1	5	9
			(2 s)	(1 s)	(1 s)		(4 s)
			50	*7 1*	*7 1*	*3[illegible] 8 %*	*64 2*
		Bile ducts	1	10	3	0	14
				(1 d)	(1 d)		(2 d)
			7 1	*71 4*	*21 4*	*0*	*100*

3[illegible] Patients (following cholecystectomy)

Patients	Remains of medium		Very good	Good	Poor	Absent	Filled
21	None	Bile duct	2	14	3	2	19
				(2 s 5 d)	(2 d)		(2 s 7 d)
			9 5	*6[illegible] [illegible]*	*14 3 %*	9 [illegible]	90 4
8	Stomach 3—5 hrs		1	2	4	1	7
				(1 s)	(2 d)		(1 s 2 d)
			1? 5	*25*	*50*	*12 5*	*87 5*
6	Small intestine 5—8 hrs		0	2	1	3	3
				(? d)	(1 d)		(3 d)
			0	*33 3*	*1[illegible] 6*	*[illegible]0*	*50*

s Stones
d Dilated bile duct

The demonstration of the bile ducts was poorer if there were residues in the stomach whereas if they were found in the small intestine the filling of the bile ducts in patients with intact gallbladders was 100 % and in those who had undergone cholecystectomy was 50 %. In those in whom no residues of medium were apparent the percentage filling of the bile ducts was very good

Analysis of results in patients over 60 The reliability of peroral cholegraphy in elderly subjects in whom the risk of administering Biligrafin is greater (SALTZMAN) was considered to be of special interest The results of investigations in 46 patients aged from 60 to 81 years were separately analysed five of these had been subjected to cholecystectomy The results are shown in Table 9

Table 9

Analysis of the results of 41 peroral cholegraphies in patients over 60 years of age

Patients		Very good	Good	Poor	Absent	Filled
41	Gallbladder	13 (2 s) *31 7 %*	5 (3 s) *12 1 %*	6 (5 s) *14 6 %*	17 *41 5 %*	24 (10 s) *58 5 %*
	Bile ducts	7 (1 d) *17 %*	19 (4 d) *46 3 %*	11 (1 s 3 d) *26 8 %*	4 *9 8*	37 (1 s 8 d) *90 2 %*

s = Stones
d = Dilated bile ducts

The gallbladder was filled in 58 5 % and the bile ducts in 90 2 % of the patients Stones were found in the gallbladder in 10 and in the bile ducts in one patient The bile ducts were demonstrated well in 2 and poorly in one of the five patients who had been subjected to cholecystectomy

Peroral cholecystography had previously been carried out in 30 patients of this group The filling of the gallbladder was very good in 2 and poor in one, while in 27 patients (90 %) it was not demonstrated In 14 (51 4 %) of these 27 patients the gallbladder was filled by Biloptin or Solu Biloptin with the standard method Stones were found in 8 of these 27 patients, and the bile ducts were demonstrated in 23 (85 1 %)

A control examination with Biligrafin was carried out in 17 patients over 60 years of age The finding was identical in 13 patients, although Biligrafin produced a better contrast density of the gallbladder in 3 and of the bile ducts in 7 patients The findings with Biligrafin rather differed in 4 patients in one the gallbladder, which had not been filled with Biloptin, was outlined with Biligrafin and was seen to contain stones, while in 3 patients the bile ducts were well filled with Biligrafin and in one contained stones that had not been shown with Biloptin

Side effects were carefully investigated in 40 patients Nausea occurred in 12 patients (30 %), diarrhoea in 3 (7 6 %) and vomiting in one patient (2 5 %) Twenty four patients (60 %) had no disturbances

Contrast residues were studied in all 46 patients They were found in the stomach in 12 patients (26 %) and in the small intestine in 5 (10 8 %) None were evident in 29 patients (63 %)

The gallbladder in the patients over 60 was thus filled with 10 % lower frequency than in the total material, or 13 5 % compared with the results of filling in the group of patients under 60 The percentage filling designated 'very good' was also a little lower Furthermore, the gallbladder was filled much more frequently by the standard method with Biloptin or Solu Biloptin

than with the media and the technique used for the common peroral chole cystography The results of the filling of the bile ducts were practically identical with those in the younger patients except in those who had undergone chole cystectomy in whom they were not so good The side effects and resorption in the older subjects did not differ from the average obtained in the whole group

It is felt that these facts argue for the exhibition of peroral cholegraphy as the examination of choice in elderly subjects

Causes of failure with peroral cholegraphy The gallbladder and bile ducts were not filled in 26 patients of the material 6 of whom had undergone cholecystec tomy Damage of the excretory function of the liver could be established in 15 patients of this group The conditions for filling were unfavourable in 4 pa tients due in two to changes brought about by operative procedures in one to an internal fistula between the gallbladder and the colon and in the fourth patient to carcinoma ventriculi with pyloric stenosis No explanation for the non filling was forthcoming in 7 patients of the material

Side effects were studied in 21 patients of this group Thirteen (62 %) had no disturbances 7 had nausea and only one (4 7 %) vomited contrast medium These figures are within the average limits except that there was no report of diarrhoea in this group

Contrast residues were investigated in all 26 patients Residues were evident in the stomach at 3 to 5 hours in 9 (34 6 %) and in the small intestine at 5 to 8 hours in 3 patients (11 5 %) No remnants were found in 14 patients (53 8 %) The slow emptying of the stomach and disturbances in resorption may have contributed to some of the non filling in this group

A control with Biligrafin was carried out in 10 patients (two of whom had undergone cholecystectomy) with evidence of slight to severe damage of the liver The gallbladder was filled in only one and contained stones although the bile ducts were demonstrated in 7 of these patients and in 2 contained stones morphine was injected in one of the latter patients

Filling of the gallbladder was successful with Biligrafin only in one of 6 pa tients (two of whom had undergone cholecystectomy) with no evidence of liver insufficiency The bile ducts filled with Biligrafin in all 6 patients in one after morphine stones were revealed in one of these

Accordingly the gallbladder was filled with Biligrafin only in 2 while the bile ducts were filled in 13 of the 16 patients in whom no filling had been ob tained with Biloptin

Disturbances of liver function and of resorption of the contrast medium com bined with the obstruction of the cystic duct may be assumed to be the chief cause of the complete failure with peroral cholegraphy In these circumstances Biligrafin proved to be only a little more reliable in the filling of the gallbladder while in the demonstration of the bile ducts it has shown to be definitely su perior

Discussion

Biloptin was mostly used in this material One of the advantages of Solu Biloptin over Biloptin is that the suspension is more easy to take than the capsules (GOERKE, SALTZMAN, WALTHER) SALTZMAN stated that only 11 of his 61 patients found Solu Biloptin unpleasant Most authors believe that side effects are not so frequent with Solu Biloptin although MURRAY reported more vomiting and diarrhoea with Solu Biloptin than with Biloptin

Of 21 of the patients of the present material who were examined with Solu Biloptin, six had nausea, two diarrhoea and one vomiting, which corresponds to the average observed with Biloptin The evacuation of Solu Biloptin from the stomach seems to be faster than that of Biloptin (KOHLER & HOLSTI, GOERKE, PFLOSCHEK), while the *resorption in the small intestine is slower* (PFLOSCHEK) WHITESIDE, in his material of 120 examinations performed with the fractionated method, found residues of the second dose of Solu Biloptin in the stomach at 2 to 3 hrs in 12, and residues of Biloptin at 3 to 4 hrs in 6 instances The present material of 21 patients has revealed residues of Solu Biloptin in the stomach in 5 and in the small intestine in 6 patients The percentage of residues in the small intestine in this small group is much higher (23 8 %) than in the whole material (8 4 %)

The percentage of 68 5 % filled gallbladders in the present material is higher than those of LUDIN & LAUCHENAUER's (59 %) and ROBINSON's (57 %) and nearly the same as that of PFLOSCHEK's Better results were achieved by GOLMALIE (84 %) in a material of 26 patients, by KONNER (86 %), and by RICHTER et coll (83 5 %) who examined only out patients The authors who used the fractionated method have a higher average of filled gallbladders than that obtained in the present material (KEMP & WRIGHT 94 1 %, WHITESIDE with *Biloptin (I)* 90 % *and a combination of Biloptin and Solu Biloptin (II)* 77 %, WALTHER 79 4 %, MURRAY 74 3 %) Exceptionally, SCHACHERL published a figure of only 62 %

The present writers consider that the percentage of filling of the gallbladder in their material may be partially conditioned by the selection of patients, because especially in the last 18 months Biloptin and Solu Biloptin have been mostly used when cholecystography has failed to demonstrate the gallbladder It may be that the relatively long period between the administration of the *medium* and the obtaining of films, which is characteristic of the fractionated method, may, as the contrast bile becomes more concentrated by the loss of water, be some factor in the demonstration of the gallbladder Biloptin and Solu Biloptin are *however excreted from the liver in high concentration*, and the dehydration in the gallbladder is consequently not so important Furthermore, nearly the same conditions as those of the fractionated method may be achieved, if necessary, by prolongation of the examination

Like WHITESIDE and KEMP & WRIGHT, the present authors found that the diseased gallbladder was easier to fill by Biloptin and Solu Biloptin than by

any other oral contrast medium There are however some divergent opinions WHITE & FISCHER using a double dose of Oragrafin (the trade name for Biloptin in the USA) stated that demonstration of the gallbladder is not more frequent than with a double dose of Telepaque ROBINSON stated that using the 3 hour Solu Biloptin method nonopacification is not an acceptably reliable indication of gallbladder pathology

Far reaching conclusions on the state of the mucosa of the gallbladder the diagnosis of cholecystitis based upon the intensity of the contrast medium hardly appear justified This appears to hold for cholegraphy as it does for cholecystography (BUCHTALA and WALTER)

The percentage of outlined bile ducts in the present material (90 %) is nearly the same as that of SALTZMAN s and KOHLER & HOLSTI s (92 %) The filling of the bile ducts in the present material was good in 49 5 %, poor in 24 5 % and very good in only 16 % of patients while the bile ducts were not represented at all in 10 % SALTZMAN who used morphine reported diagnostically adequate contrast density in 82 % not distinct enough for diagnosis in 10 % and 'not visible in 8 % of patients KOHLER & HOLSTI designated only 7 % as excellent 32 % as good and 52 % as poor The percentage of filling of the bile ducts with a double dose in works of other authors is lower LEDIN & LAUCHENAUER 62 % ROBINSON 57 % BORIS & SILLO 74 % MULLER et coll 75 % KONNER 74 2 % and RICHTER et coll 53 3 % The fractionated method produced the following results WHITESIDE 86 % out of 120 patients GOERKE 70 % BOGATZKI 65 % good and 26 % poor SCHACHERL 54 %, while MURRAY reported only 38 (19 %) clear demonstration of the bile ducts and 44 (22 %) poor a total of 82 (41 %) out of 198 examinations

WALTHER succeeded in filling the bile ducts with the double dose in 5 of 8 patients who had had cholecystectomy GOERKE produced filling in 3 out of 5 and KONNER in 3 out of 8 such patients The results of filling of the bile ducts in similar patients in the present material (29 out of 35 or 82 8 %) and the relation between the groups are considering the quality of the demonstration only slightly poorer than in the group of non operated patients

It may be stated in general terms that the filling of the bile ducts achieved with a double dose of Biloptin or Solu Biloptin is quite reliable Should the gallbladder not be outlined filling of the bile ducts will be evidence of normal resorption from the intestine and of good excretion from the liver and the diagnosis of obstruction of the cystic duct may be made in such cases with more confidence than in peroral cholecystography

The fractionated method appears to be less convenient and less reliable than the standard method for the study of the bile ducts As the optimal concentration of Biloptin and Solu Biloptin in the bile ducts occurs in 3 hrs only one dose — the morning one — takes part in the filling by the fractionated method The whole of the double dose of contrast medium produces the filling of the bile ducts in the standard method

Although all authors agree that the side effects and complications with Biloptin and Solu Biloptin are not so frequent as with other media, reports on their percentages would appear to vary. Boris & Sillo and Schacherl reported no side effects and Muller & Sielaff, Robinson and Goerke described only minor symptoms. Other authors mentioned the following side effects: *nausea* (using double dose): Ludin & Lauchenauer and Saltzman 22 %, White & Fischer 20 %, Kohler & Holsti 8.6 %, (fractionated method) Whiteside I 35 % and II 13.3 %, Murray (Biloptin (I)) 32.6 % and (Biloptin and Solu Biloptin (II)) 36.6 %, Walther 14 %, Kemp & Wright 15 %; *diarrhoea*: White & Fischer 26 %, Ludin & Lauchenauer 7 %, Whiteside (I) 12 % and (II) 6.6 %, Murray (I) 5.1 % and (II) 22 %, Walther 3 %, Kemp & Wright 5 %, while Saltzman and Kohler & Holsti reported no case of diarrhoea; *vomiting*: Saltzman 1.6 %, Kohler & Holsti 5 %, Konner 2 %, Whiteside (I) 12 % and (II) 6.6 %, Murray (I) 6.3 % and (II) 14.6 %, Kemp & Wright 7.7 % and Walther 2 %. One allergic reaction was reported by Brannan et coll., by Ludin & Lauchenauer, and by Kemp and Peloschek, while Whiteside reported two such reactions.

The side effects were nearly the same with the fractionated as with the standard method in the present comparative examinations. It would appear that the percentages of side effects in the present material — nausea 29.2 %, diarrhoea 7.2 %, vomiting 4.5 %, headache 1.8 % and allergic reaction 0.4 % — do not constitute contra indications for the employment of the standard method, especially as such symptoms do not materially affect the demonstration of the biliary tract.

Resorption of the contrast medium is not discussed at length in the literature. Ludin & Lauchenauer found residues in the abdomen at 7 hrs in 48 % of patients while Konner reported residues in 50 %. Peloschek mentioned remnants of Biloptin in the stomach at 4 ½ hrs in 23.8 % and of Solu Biloptin in 8.7 % of patients, while at the same time he found residues of Biloptin in the small intestine in 23.9 % and of Solu Biloptin in as many as 47.8 % of patients.

The present results (residues in the stomach at 3 to 5 hrs in 29.6 % and in the small intestine at 5 to 8 hrs in 8.4 % of patients) correspond to the average. The long period of evacuation from the stomach and the slower resorption in the small intestine affect more the demonstration of the gallbladder than the bile ducts, as the analysis shows.

Comparative examinations made by Ludin & Lauchenauer, Peloschek, Walther and Schacherl established that the filling of the gallbladder was only slightly more reliable with Biligrafin than with the peroral cholegraphic media. Konner and Richter et coll. found no differences in the demonstration of the gallbladder with Biligrafin and Biloptin. Ludin & Lauchenauer succeeded in filling the bile ducts with Biligrafin 83 % and with Biloptin in only 62 % of patients, the percentages of "very good" filling for Biligrafin being 32 % and for Biloptin only 7 %. Kohler & Holsti managed to show the bile

ducts with Biligrafin designated as excellent in 53 % but with Solu Biloptin only in 7 % of patients the percentages of filling in 61 patients being 96 % for Biligrafin and 92 % for Solu Biloptin WALTHER was able to demonstrate the bile ducts with Biligrafin in 14 instances in which they had not been filled with Biloptin while in 5 patients no filling was obtained

The findings at control examination with Biligrafin were identical with those of the peroral cholegraphic contrast media in 61 % of the patients of the present material Gallbladders that were not demonstrated with Biloptin were out lined with Biligrafin in 10 patients while the opposite occurred on two oc casions The bile ducts that were not filled with Biloptin were outlined with Biligrafin in 13 patients It would appear that these results justify the employ ment of Biligrafin in those patients in whom the gallbladder is not filled with Biloptin especially if the bile ducts are not, or only poorly outlined It is evident that peroral and intravenous cholegraphy are not separate but com plementary methods The high percentage of filled bile ducts in the present material — 90 % in non operated patients and 82 8 % in those who had had their gallbladders removed — justifies the use of the peroral cholegraphic contrast media administered by the standard method when selecting the ma terial for subsequent examination with Biligrafin

Conclusions

The method of administering a double dose of a peroral cholegraphic contrast medium on an empty stomach produces simultaneous filling of the gallbladder and bile ducts, or of the latter alone if the gallbladder is occluded or has been removed As these contrast media are excreted from the liver *in* high concentration the demonstration of the gallbladder is quite independent of the ability of the mucous membrane of the gallbladder to *concentrate* A pathologically changed gallbladder may consequently more often be filled by this method than by peroral cholecystography The success of the examination depends first and foremost on liver function the resorption in the intestines and the patency of the bile ducts may be checked roentgenographically

The side effects are mild and except vomiting do not influence the results of examination

The time of examination is reduced to 3 to 5 hours

The method of giving a double dose of Biloptin or Solu Biloptin on an empty stomach is the most *suitable* one for use in out patient examinations and most dependable although other methods may be indicated under certain condi tions

Peroral cholegraphy appears to be the method of choice in older subjects and in those allergic to Biligrafin

It may be said that the density of filling of the bile ducts is somewhat greater in intravenous cholegraphy with Biligrafin and the demonstration of the stone

filled gallbladder rather more dependable. However, by controlling the course of the examination, and with the help of tomography, the results obtained with Biloptin or Solu Biloptin may be further improved so as to approach more closely those achieved with Biligrafin. The employment of intravenous cholegraphy may be accordingly reduced and confined to cases in which the peroral cholegraphy has failed.

The hepatobiliary system must be considered as an entity and any functional and morphologic changes in the gallbladder and bile ducts regarded as aberrations in a system. It would appear, therefore, that peroral cholegraphy will gradually replace peroral cholecystography.

SUMMARY

The results of 249 peroral cholegraphies performed with a double dose of Biloptin or Solu Biloptin are reported. The influence of side effects, resorption of the medium and age are discussed. Peroral cholecystography and peroral and intravenous cholegraphy are compared and the conclusion is reached that peroral cholegraphy may be expected gradually to replace peroral cholecystography and also in many instances make intravenous cholegraphies superfluous.

ZUSAMMENFASSUNG

Es wird über 249 perorale Cholegraphien nach Verabreichung einer Doppeldose von Biloptin oder Solu Biloptin berichtet. Der Einfluss von Nebenerscheinungen, Absorption des Kontrastmittels und Altersdifferenzen werden besprochen. Perorale Cholecystographie und perorale und intravenose Cholegraphie werden verglichen mit dem Resultat, dass die perorale Cholegraphie wahrscheinlich allmählich die perorale Cholecystographie ersetzen kann und ebenso in manchen Fällen intravenose Cholegraphien überflüssig macht.

RÉSUMÉ

Les auteurs présentent les résultats de 249 cholégraphies orales faites avec une double dose de Biloptin ou de Solu Biloptin. Ils étudient l'influence des effets secondaires, de la résorption du moyen de contraste et de l'age. Ils comparent la cholécystographie orale et la cholégraphie orale et intraveineuse et concluent que sans doute la cholégraphie orale remplacera graduellement la cholécystographie orale et en bien des cas rendra inutile la cholégraphie intraveineuse.

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LEAD COATING OF THE TRICUSPID VALVE IN DOGS

by

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The purpose of this study has been to develop a method of applying a thin coating of an adhesive plastic impregnated with radiopaque material to the endocardial surface of the dog s heart which would be compatible with survival and well tolerated This would provide an approach for studying, with the aid of cineradiography on long term basis and under physiologic conditions the dynamics of the cardiac valves and changes in volume and shape of the four cardiac chambers in the dog recovered from thoracotomy

A method for long term studies of the intricately coordinated function of the valvular leaflets ostial rings chordae tendineae myocardium and papillary muscles is not available at the present time Information about the function of the cardiac valves obtained by a number of other examination methods is incomplete because the methods are indirect non physiologic or not suitable for long term observations Intracardiac pressures phonocardiography measurement of flow and electrokymography have been used to study the function of the valves but these methods are all indirect

Visual demonstration of the function and morphologic features of the cardiac valves has been made possible with the aid of angiocardiography after injection of contrast medium into the cardiac chambers or into the large juxta cardiac vessels but only under favorable conditions do the valvular leaflets appear as

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defects in blood and contrast medium mixture In diastole the normal aortic and pulmonic valves have been studied by the injection of contrast medium just above the valve The function of normal tricuspid and mitral valves, however, cannot be studied with analogous methods Information is also available about stenotic valvular disease by angiocardiography as the blood stream is held up for some time at the site of the obstruction and the contour of the valvular leaflets can thus be delineated As a method for long term studies of the function of the cardiac valves and related structures, angiocardiography is not suitable, for several reasons The time available for study of the valvular action is too short because of the fast passage of the blood contrast medium mixture The repeated administration of large amounts of contrast medium has profound effects upon the cardiovascular function, and is toxic Simultaneous studies of the right and left side of the heart are not possible Filling of the cardiac chambers with carbon dioxide has been used for the study of cardiac valves (OPPENHEIMER et coll 1956) Many of the drawbacks mentioned above apply also to this method

To overcome the difficulties, attempts have been made to make visible the cardiac valves and study their motility with the aid of cineradiography RUSHMER et coll (1956) tried to demonstrate the mitral valves in dogs with Lipiodol injection and study the valvular function with cineradiography This method was not successful They then tried silver clips, which were attached to the mitral valves during open heart surgery, and the valvular function was studied with the aid of cineradiography This method, however, did not enable all structures involved in the valvular function to be demonstrated simultaneously

Calcifications in the cardiac valves in humans makes the study of the valves possible by cineradiography (BARTLEY 1958) Such studies have obvious limitations

Furthermore, motion picture studies of the valvular action of hearts perfused with saline cannot be performed in the intact animal Under these conditions it is impossible to measure the amplitude of movements of the involved structures (MCMILLAN 1955)

Preliminary investigations have been in progress in our laboratory in an effort to develop a plastic adhesive containing radiopaque material which could be applied to the cardiac valves and intracardiac structures of dogs The adherence of this radiopaque adhesive to the endocardial surface makes it possible to demonstrate the cardiac dynamics with cineradiography in the intact closed chest animal on a long term basis and under a great variety of experimental conditions

Method Six mongrel dogs weighing between 15 and 25 kg were anesthetized with nembutal and subjected to total body perfusion with a laboratory pump oxygenator designed by one of the authors (LOVE 1962) Hypothermia of 30 to



Fig 1 a) The tricuspid ostium and valve in a dog coated with lead powder and adhesive The contrast medium accumulation covers a part of the inner surface of the right ventricle 6 hours after operation b) 10 days after operation The surface coating is essentially the same as in (a) The projection and object film distance are somewhat different

32 C was used to permit aortic cross clamping for 5 to 10 minutes Cross clamping of the aorta interrupts the blood flow through the coronary vessels to the right atrium The blood flow from the venae cavae was directed through the pump oxygenator and re entered through the femoral artery In this way the necessary dry field for contrast medium application was obtained Exposure was accomplished in each case through a right atriotomy The contrast medium was applied with small cotton swabs to the tricuspid valve No measures were taken to prevent thrombosis The contrast medium was a mixture of fine lead powder and Eastman 910 Adhesive (Eastman Kodak Company Rochester New York) The lead powder grains measured 200 mesh or less Chemically it consists of methyl cyano-acrylate which is modified with a thickening agent and a plasticizer This adhesive has been used by HEALEY et coll 1962) for the nonsuture repair of blood vessels It is self sterilizing and the setting of the adhesive does not depend upon evaporation or heat cure No catalyst is needed Polymerization occurs spontaneously when the adhesive forms a thin layer Lead powder and adhesive were mixed only a few minutes before the application in order to avoid premature polymerization About five hours after the operation and then at varying intervals the dogs were ex



Fig 2 Section from the valve shown in fig 1 A large collection of lead powder is enclosed by newly formed endothelium 24 days after the application of lead The amount of lead adhesive mixture shown is many times larger than the one necessary for an adequate roentgenographic demonstration of the valve

amined with cineradiography and serial cardiography The animals were necropsied 6 to 24 days after the application of contrast medium and the valves were examined microscopically in 2 dogs, 14 and 24 days after operation

Results and Discussion

Three dogs succumbed, one from irreversible ventricular fibrillation during the cardiotomy, one from large blood loss at operation, and one from bleeding into the pleura in the postoperative course In all dogs, a coating of the tricuspid valve was obtained, which could not be washed off with saline

The three surviving dogs were killed 6 14, and 24 days after the application of the surface coating contrast medium Microscopic examination of the tricuspid valve was performed in the two dogs sacrificed 14 and 24 days after operation

Sections of the heart valves showed a non specific, acute and chronic inflammatory reaction, with early fibrosis completely surrounding the lead adhesive mixture Foreign body giant cells were not a prominent feature An endothelial layer formed over the lead adhesive mixture and its associated reaction (Fig 2) (Dr Saltzstein from the Department of Pathology examined the specimens grossly and microscopically) Thrombosis was found adjacent to the lead adhesive mixture but in one of the dogs a thrombus had formed under the septal leaflet of the tricuspid valve

All dogs were subjected to roentgen examination of the heart and the three survivors were also examined with cineradiography and serial cardiography. The movements of the tricuspid ring and the leaflets were well seen (see Fig. 1).

The lead adhesive mixture forms a brittle substance which breaks in areas where there is gross movement. Ideally the mixture should form a flexible substance to give a true picture of the valvular movements. If, however, the mixture is applied in a thin layer, the drawbacks of the brittleness are reduced and the lead adhesive mixture will move with the valves.

In the studies described above, the lead adhesive mixture was applied to the tricuspid valves by opening the heart after resection of a piece of the right auricular appendage. If possible, the application should be made without cardiotomy by catheter introduced from the neck or groin. Experiments using this method are in progress in our laboratory. Attempts are also made to produce stenosis of the pulmonic, aortic, tricuspid and mitral valve leaflets by application of the lead adhesive mixture.

Surface coating of the intracardiac and intravascular structures of the experimental animal with contrast medium offers a new approach to the study of the intricate intracardiac dynamics under normal and abnormal conditions.

SUMMARY

A lead adhesive mixture has been applied to the tricuspid valves in dogs after cardiotomy under extracorporeal circulation. The dogs were studied with cineradiography at varying intervals from 5 hours to 24 days after operation. The lead adhesive mixture was fixed to the endocardial surface and covered by endothelium.

ZUSAMMENFASSUNG

Eine adhäsive Bleimischung wurde auf die Trikuspidalklappe von Hunden nach operativer Freilegung und unter Umschaltung des Kreislaufes aufgetragen. Die Hunde wurden dann mittels Röntgenkinematographie in wechselnden Zeitabständen von 5 Stunden bis 24 Tagen nach der Operation untersucht. Die adhäsive Bleimischung verblieb auf der Herzklappe und wurde von Endothel überzogen.

RÉSUMÉ

Les auteurs ont appliqué sur les valvules tricuspides de chiens, après cardiotomie sous circulation extra-corporelle, un mélange adhésif contenant du plomb. Ces chiens ont été examinés par cinéradiographie à des intervalles allant de 5 heures à 24 jours après l'opération. Le mélange adhésif au plomb était fixé à la surface endocardique et était recouvert par l'endothélium.

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INSTRUMENT FOR INJECTION URETHROGRAPHY IN WOMEN

by

M J F ANDERSEN

A number of different methods of retrograde urethrography in women have been described since THOMSEN (1930) published the first reports (see references) The major technical difficulty has always been to obtain complete closure round the external urethral orifice An instrument on a principle different from that hitherto published has therefore been constructed

The instrument consists of a main part and 8 cannulae with end plates of different diameters (4 to 18 mm) the proximal end of the cannula is threaded so that the cannula can be firmly connected with the main part by a second threaded screw in the main part the distance between its headplate and the end plate of the cannula can be diminished or increased (see Fig 1)

The patient lies supine more or less in the gynaecologic position on a tilting table The external urethral orifice is inspected and a suitable cannula (connected with the main part) is introduced through the orifice after the usual cleansing of the latter The two plates are screwed together till the patient feels slight pain in the tissue held between the two plates The closure is now effective A syringe containing the contrast medium is attached to the instru

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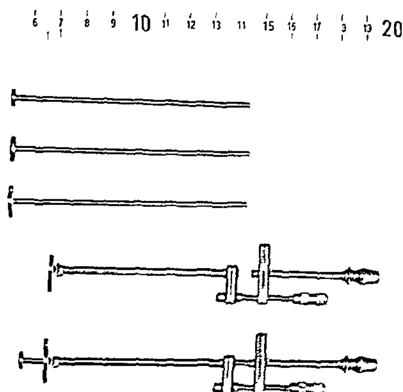


Fig 1 Instrument assembled and cannulae of different diameters



Fig 2 Normal urethrograms in oblique and lateral positions

ment and the tilting table is raised approximately 15 degrees, air is removed from the urethra by a preliminary injection of the medium, and the necessary roentgenograms are then obtained under fluoroscopic control

The author has tested the instrument in 100 cases (in subjects of from 19 to 78 years of age) with carcinoma of the genital tracts and found the method effective Some difficulty was encountered in two cases on account of the absence of sufficient tissue at the anterior commissure of the orifice and in a further three cases by reason of carcinomatous invasion of the orifice

One frontal one lateral and two oblique views are usually obtained Urografin 76 % has been found to be a satisfactory contrast medium and no patients have complained of discomfort from its use Average exposure factors with 6 valve apparatus filter Al 3 mm focus 0 9 mm focus/film distance about 60 cm, field 8 to 10 × 12 to 15 cm frontal 80 kV 32 mAs oblique 80 kV 50 mAs, lateral 120 kV 140 mAs

The instrument ensures effective closure of the orifice (Fig 2) and no local anaesthesia is required Dysuria following the investigation has never lasted more than 24 hours and no case of necrosis to the tissue of the external orifice has been encountered

The instrument is available from W Kaiser A/S Vestergade 5 Århus C Denmark

SUMMARY

A simple instrument for female urethrography is described It has been tested in 100 cases and has proved to ensure effective closure of the external orifice with little discomfort to the patient

ZUSAMMENFASSUNG

Ein einfaches Instrument fur die Urethrographie von Frauen wird beschrieben Das Instrument wurde in 100 Fallen benutzt es produzierte einen guten Verschluss des Orificium ext und verursachte kaum irgendwelche Beschwerden

RÉSUMÉ

Description d un instrument simple pour l urétrographie chez la femme Il a été essaye dans 100 cas il obture efficacement le méat et cause peu de gene a la patiente

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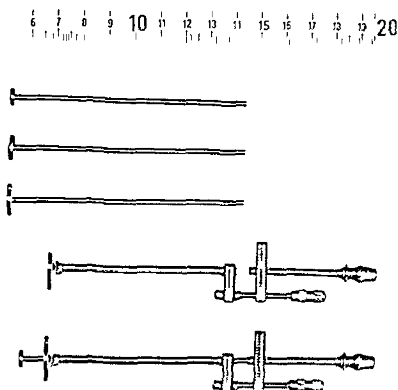


Fig 1 Instrument assembled and cannulae of different diameters



Fig 2 Normal urethrograms in oblique and lateral positions

BOOK REVIEWS

MYELOGRAPHY By Robert Shapiro Year Book Medical Publishers Chicago 1962 278 pages 236 illustrations Price 11 dollars

This book is based upon the dictum that pantopaque constitutes the best all purpose medium available although it is admitted that gas and water soluble contrast media may sometimes possess advantages Accordingly it is pantopaque myelography that is mainly de scribed and other contrast media only briefly The author s reluctance to use gas myelography may be explained by his description of its technique The importance of complete drainage of the cerebrospinal fluid and the necessity of high pressure to distend the subarach noid space are for example not mentioned The technique in myelography with pantopaque on the other hand is described in great detail It would seem to the reviewer that insufficient emphasis is placed upon the main principle i e that the heavy pantopaque mainly collects in the lower part of the subarachnoid space and that consequently the upper part is often only incompletely filled It is true that it is mentioned later that an examination in the supine position is also advisable in certain cases The normal anatomy is clearly and adequately described and the normal pantopaque myelogram with its variations as well as the results of a faulty technique are illustrated in a number of reproductions of roentgenograms It is however somewhat astonishing to read in the legend to Fig 71 that the extradural oil may be seen to coat the periphery of the cauda equina The more or less typical changes evident in pantopaque myelograms in various pathologic conditions (tumors malformations traumat ic and inflammatory lesions) are covered by a fairly large number of illustrations many of them borrowed from various papers only a few examples of gas myelograms are included Disk herniations are dealt with in a special chapter but it would appear that many of the illus trations indirectly demonstrate the superiority of water-soluble contrast media in a study of lumbar disk herniations In the description of cervical disk lesions the author apparently tries to differentiate between disk herniation osteophytic spurs lipping of the vertebral body and bulging of the nucleus with an intact annulus fibrosus It would appear hardly possible and of limited practical importance to divide up these various manifestations of disk degeneration The important question is the extent to which they affect the nerve roots and the spinal cord The last chapter is devoted to diskography in the lumbar and cervical region The significance of reproducing the patient s symptoms at the injection is only briefly mentioned

Shapiro s book may be of some help to those using pantopaque in myelography since it describes and illustrates more completely than ordinary textbooks the various lesions that may be demonstrated with this technique It would appear however to be of little value to radiologists using gas and water soluble contrast media although the fairly extensive list of references at the end of each chapter may prove useful

Ingmar Wickbom

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New Series Diagnosis

ROENTGEN DIAGNOSIS

Nervous system

Digestive tract

Heart and Vessels (incl Lymphatic vessels)

DIFFERENTIALDIAGNOSE SELTENER LUNGENERKRANKUNGEN IM RÖNTGENBILD. EIN ATLAS. Herausgegeben von K. Musshoff und J. Weinreich. 205 Seiten und 112 Abbildungen. Springer, Berlin 1962. Price DM 108.

This atlas illustrates 112 cases of pulmonary disease the majority of which may be described as rare, some would be considered by many workers as very rare while others such as sarcoidosis and bullous emphysema would perhaps be regarded as fairly common. The cases have been assembled from no less than 46 different sources a fact that may explain the slight lack of uniformity in the quality of the films which mainly consist of routine frontal views. The authors have however obviously endeavoured to illustrate different aspects of the pulmonary changes with the aid of roentgenograms of special details as well as with bronchograms and tomograms. The strength of this book lies in the concise yet surprisingly full text accompanying each case which in nearly every instance is concluded with a statement on how the histologic diagnosis was obtained. A detailed alphabetic list of diagnoses as well as a short list of references are included.

Björn Nordenström

DIAGNOSTIC PRATIQUE DES CARDIOPATHIES CONGÉNITALES. Par Jean Bret. 152 pages et 107 illustrations. L'Expansion, Paris 1962. Price 33 NF.

It is commonly acknowledged that the simple physical examination at the bedside forms the diagnostic basis in the clinical investigation of congenital heart disease. In the present work which mainly appears to be addressed to the cardiologist the author holds the view that the precordial leads in the ECG should be utilized for the purpose. He is however forced to make many modifications when applying this original theory in practice. The descriptions of the findings in chest roentgenograms and from angiocardiographic examinations are strikingly incomplete and do no justice to these methods. The large number of suitably selected schematical drawings illustrating the morbid anatomy and altered haemodynamics in all the ordinary congenital heart defects is a feature that seems to be of greatest interest to the radiologist.

Ulf Rudhe

THE ROENTGENOLOGICAL ASPECT OF NON-PENETRATING CHEST INJURIES. By John Riley Williams and Frederick J. Bonte. 135 pages, 31 illustrations and 4 tables. Charles C. Thomas, *Springfield, Ill. 1962.*

The book is a review of our present knowledge of non-penetrating chest injuries presented in a short and practical way.

Some historical notes are given in the introduction in which it is stated that Morgagni in 1761 described the first case of lung contusion as a result of a fall. The mechanism of injury in non-penetrating trauma of the chest is discussed both from experimental and clinical viewpoints. The different topographic areas of the chest are dealt with in separate chapters, and entities such as pulmonary contusion and haematoma, diaphragmatic hernia, tracheo-esophageal fistula, *aortic aneurysm* and cardiac septal lesions are described. The fact that some non-penetrating chest injuries are apparent soon after the trauma while others will be demonstrable only weeks or months later is stressed. The account of possible injuries is almost complete but the reviewer noticed that in the section on arterial rupture and aneurysm formation lesions of the subclavian arteries and the brachio-cephalic trunk were not mentioned.

The book is made up of 131 pages and 78 roentgenograms and includes an extensive bibliography (341 references). In view of the increasing and unending number of traffic accidents the need for rapid and accurate *roentgen diagnosis and the conspicuous absence of the relevant* information in the ordinary textbooks make this compact and handy book a valuable contribution to the subject of its title.

Erik Carlsson

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TECHNIQUE

Roentgen examinations

Contrast media

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